United States Department of Agriculture
Forest Service

Francis Marion National Forest

Draft Forest Plan Assessment

Francis Marion National Forest, Berkeley and Charleston Counties, South Carolina

2.2 Air, Soil, and Water Resources and Quality

December 2013

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Francis Marion National Forest
Draft Forest Plan Assessment
Berkeley and Charleston Counties, South Carolina

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2.2.1 Air

2.2.1.1 Preliminary Findings

▶Air pollution emissions of sulfur dioxide, nitrogen oxides, ammonia, fine particulate matter, and mercury have the greatest potential to impact the natural resources and the services they provide on the Francis Marion National Forest.

▶Annual emissions of sulfur dioxide and nitrogen oxides had large deceases between 2002 and 2008. Emissions of fine particulate matter from Forest Service prescribed fires probably increased between 2006 and 2011 as well as other source in the region.

▶None of the National Ambient Air Quality Standards (NAAQS) are exceeded within or near the National Forest.

▶There has been a significant decline in fine particulate matter concentrations between 2004 and 2010 for both the daily and annual NAAQS, even with an increase in the number of acres treated with prescribed fires on the Francis Marion National Forest.

▶Regional air quality planners have utilized information provided by the Forest Service on the location, timing, size, and amount of fuel consumed for 2002, as well as forecasts for 2018, for NAAQS and Regional Haze planning. The 50,569 acres treated with prescribed fires in 2010 did exceed the 2018 forecast of 45,000 acres, but the NAAQS was attained at the closest ambient monitors and reasonable progress in visibility conditions was attained at the nearby Cape Romain National Wildlife Refuge (a federally mandated class I area).

▶There has been a significant decline in the sulfate and total nitrogen deposited from rainfall between 1983 and 2011 on the Francis Marion National Forest.

▶Most (64 percent) of the Forest has acidic deposition levels below a level to maintain the long-term health of the ecosystem. About 24 percent of the lands within the proclamation boundary may have excessive acidic deposition. Further soil sampling, ecosystem modeling, and information gathering should be conducted before a final determination can be made on how much more acidic deposition needs to decrease to protect the long-term health of the ecosystems.

Under the 2012 Planning Rule, National Forests and Grasslands are required to consider air quality when developing plan components. As set forth in the rule, air resources should be treated similarly to water and soil resources. The recently proposed planning rule directives require the following to be included in the air quality section of each National Forest's Assessment:

1. Airshed identification;
2. Location and extent of known sensitive air quality areas;
3. Emissions inventories, conditions and trends;
4. Analysis of state implementation plans; and
5. Critical loads identification, as appropriate.

2.2.1.2 Existing Information

Current Forest Plan. The overarching goal regarding air quality in the current Francis Marion National Forest plan is to "take care of the land by continuing to restore and sustain the integrity of its…air". The desired future condition is to maintain air quality, and ensure that air quality near Cape Romain National Wildlife Refuge complements the high air quality standards found at that class I area. The plan recognizes that portions of the Forest may experience some localized and temporary reductions in air quality due to prescribed burning. The Forest plan requires the use of best and emerging smoke management technologies to reduce downwind impacts from smoke and ensure compliance with the Clean Air Act (including visibility at the nearby class I area) and South Carolina's Smoke Management Guidelines. Per the Forest plan, all management activities, not just prescribed fire, should comply with air quality standards.

Current Air Quality Concerns. In addition to causing human health concerns, air pollution can also affect natural and scenic resources such as lakes, streams, plants, wildlife, and scenic vistas. Each year air pollution sources including power plants, industrial facilities, automobiles and wildland fires, release millions of tons of pollutants into the atmosphere. These pollutants, either by themselves or after chemical transformations in the lower atmosphere, can cause negative impacts to ecosystems, including changes to soil and water chemistry from acidic deposition, nutrient enrichment (i.e., nitrogen saturation) from too much nitrogen deposition, impacts to sensitive vegetation due to elevated ozone exposures, and increased visibility impairment (or haze) in scenic areas.

Air pollutants of most concern to natural resources on the Francis Marion National Forest include ozone, particulate matter, sulfur dioxide, nitrogen oxides, and mercury. Ozone is a pollutant formed by emissions of nitrogen oxides and volatile organic compounds in the presence of sunlight. Nitrogen oxides (NO_x) are released when any fuel is combusted at very high temperatures; major sources of NO_x include automobiles, power plants, and industrial boilers. Volatile organic compounds (VOCs) are emitted from both manmade and natural sources, including chemical manufacturing, gasoline-powered vehicles, trees and other vegetation. Research has shown that in the southern U.S. there is an overabundance of naturally-occurring VOCs, and thus ozone formation is "NO_x-limited." This means that the concentration of ambient ozone is primarily dependent on the amount of nitrogen oxide emitted into the air. When ozone is formed, it causes human health concerns as well as negative impacts to vegetation. Specifically, elevated ozone concentrations can reduce the health and vigor of sensitive vegetation and reduce plant growth. The U.S. Environmental Protection Agency (EPA), as directed by Congress, has set a national ambient air quality standard (NAAQS) of 0.075 parts per million (ppm) to protect both human health and the environment.

Particulate matter is a mixture of extremely small particles made up of soil, dust, organic chemicals, metals, and sulfate and nitrate acids. The size of the particles is directly linked to health effects, with smaller particles causing the worst impacts to human health. Additionally, particulate matter is the main cause of visibility impairment. These tiny particles absorb and reflect light which diminishes spectacular views in national forests. Regional haze usually covers large geographical areas, and many local and regional sources of pollution contribute to the degraded visibility conditions. EPA has set NAAQS for ultra-small (less than 2.5 microns in diameter) particulate matter on both a short-term (24-hour) and annual basis to protect human health and visibility. The 24-hour fine particulate matter ($PM_{2.5}$) NAAQS to protect both humans and the environment is currently set at 35 $\mu g/m^3$ (micrograms per cubic meter), while the annual $PM_{2.5}$ NAAQS for human health is 12 $\mu g/m^3$.

Sulfur and nitrogen deposition can cause stream acidification and leaching of important soil nutrients needed for healthy terrestrial and aquatic biota. Nitrogen deposition can also cause eutrophication or nutrient enrichment that negatively impacts water quality, aquatic biota, and may increase invasive plant growth. Sulfur comes primarily from the combustion of coal at electrical generating units. Nitrogen compounds are derived from both the combustion of fuel at very high temperatures (such as in power plants, industrial boilers, and automobiles) as well as from various agricultural processes. Although EPA has considered setting a multi-pollutant NAAQS to address deposition-related affects, they have decided there currently is not enough scientific information to set one standard that would adequately protect the diverse ecosystems across the country.

Mercury is another important environmental contaminant that reaches forests primarily through atmospheric deposition. The primary source of anthropogenic (manmade) mercury is the combustion of coal. Mercury is fairly stable and accumulates in the environment until conditions are right for dispersal. This can occur by wildland fires ejecting the mercury back into the atmosphere, or when associated with wetlands it can be converted via sulfate reduction to its most toxic form, methyl mercury (MeHg). The MeHg is ingested by aquatic organisms and bioaccumulates as it is transported through the food web, and can affect humans when too many fish are consumed in a short period. Unhealthy levels of MeHg have led to fish consumption advisories in almost every state. Methyl mercury has also been found in numerous species of wildlife. EPA regulates the amount of mercury that is emitted into the air from many different sources, including power plants, municipal waste combustors, and medical waste incinerators. Additionally, each state is required by EPA to develop a list of water bodies that do not meet water quality standards—including those impaired by mercury, if applicable—and establish total maximum daily loads (TMDLs) for these waters.

Air pollution can come from local sources, such as activities within the national forests, or may be transported from sources hundreds of miles upwind by weather patterns. Therefore, it is important to identify the airshed around an area of interest, such as the Francis Marion National Forest. An airshed is defined as a geographic area that, due to topography, meteorology and/or climate, is frequently affected by the same air mass. For the purposes of this assessment, the airshed for the Francis Marion is defined as the counties that fall within a 124-mile radius around the Forest. Figure 2-1 shows the counties (shaded) located within 124 miles of the Forest as well as known sensitive air quality areas. These sensitive areas include the location of class I and nonattainment areas within the designated airshed. As shown, the only class I area is Cape Romain National Wildlife Refuge, located just east of the Forest. There is one nonattainment area partially located within the airshed, the Charlotte-Rock Hill Nonattainment Area for ozone. There are no other nonattainment or maintenance areas within the airshed.

Figure 2-1. Map of Francis Marion National Forest airshed (shaded) and known sensitive air quality areas

2.2.1.3 Current Condition and Trends

To assess current air quality conditions and trends on the Francis Marion National Forest, there are four categories of data to examine. The first category involves inventories of emissions from air pollution sources both on and off the Forest. The second category includes measured ambient concentrations of air pollution, especially ozone and fine particulate matter. The third category of data is measured deposition of sulfates, total nitrogen, and mercury. Finally, the last category of data includes any site-specific monitoring of air quality impacts (e.g., ozone surveys) that has occurred on the Forest.

Air Pollution Emissions Trends

The National Emissions Inventory (NEI) (http://www.epa.gov/ttn/chief/eiinformation.html) was used to assess the historic trends of air pollution emissions near the Francis Marion National Forest. Local, state, and tribal air regulatory agencies are required by the EPA to periodically inventory the amount of emissions within their respective jurisdictions. These inventories form the basis for air pollution trends analysis, air quality modeling efforts, and regulatory impact assessments. At this time, the NEI website has inventory data for the years 2002, 2005, and 2008 available for download. County emissions estimates for the 59 counties that fall within 124 miles of the Francis Marion National Forest were downloaded and compiled for each of 3 years.

The pollutants that are of most concern to resources on the national forests are those that have the potential to cause the negative impacts that have been outlined previously in section 2.2.1. Of those, the NEI inventories emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM). Table 2-1 shows the total emissions within the airshed for each of these pollutants for 2002, 2005, and 2008.

Table 2-1. Emission of sulfur dioxide, nitrogen oxides, and particulate matter within the airshed for the years 2002, 2005, and 2008

Pollutant	Emissions (tons/year)			Percent (%) Change in Emissions (2002–2008)
	2002	2005	2008	
Sulfur Dioxide (SO_2)	382,580	380,422	260,698	-31.8%
Nitrogen Oxides (NO_x)	425,217	386,348	350,047	-17.7%
Particulate Matter < 10 µm in diameter (PM_{10})	347,000	352,730	329,259	-5.1%
Particulate Matter < 2.5 µm in diameter ($PM_{2.5}$)	103,769	112,506	114,651	+10.5%

The reductions identified above mirror national trends as outlined in Our Nation's Air: Status and Trends through 2010 (http://www.epa.gov/airtrends/2011/report/fullreport.pdf). Since 1990, annual emissions of SO_2 have declined by more than 60 percent, while emissions of NO_x have fallen by more than 40 percent in the United States. These reductions have taken place despite increases in population, energy consumption, and the number of miles driven. Figure 2-2 shows these trends. Trends on mercury emissions, another pollutant of concern, have been difficult to evaluate due to the lack of appropriate emission factors, lack of speciated data, and lack of acceptable tests for mercury-emitting sources (South Carolina Mercury Assessment and Reduction Initiative, 2010).

Emission reductions over the past decade have been achieved as a result of new regulations, voluntary measures taken by industry, and the development of public-private partnerships. It is expected that air quality will continue to improve as recently adopted regulations are fully implemented, and as a result, it is anticipated that emissions of air pollution released within 124 miles of the Francis Marion National Forest will continue to decline.

In addition to emissions of sources near the Forest, emissions from Forest activities, specifically prescribed fire, were calculated. Figure 2-3 shows the trends in fine particulate matter emissions from prescribed fires on the Francis Marion National Forest from 2006 through 2011.

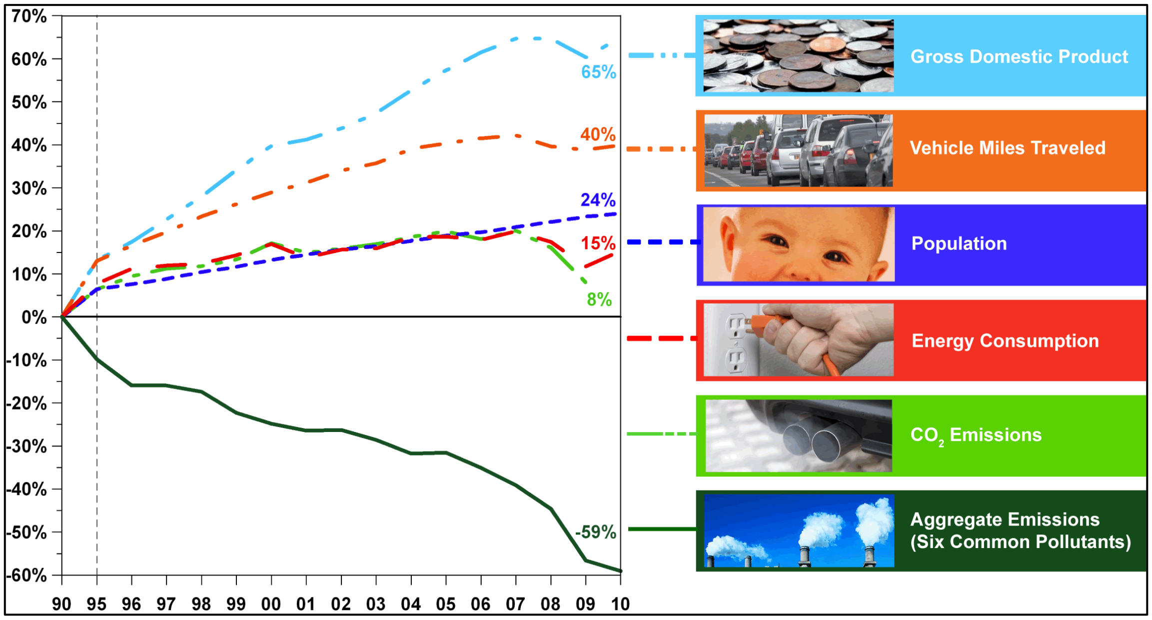


Figure 2-2. Comparison of growth measures and emissions, 1990–2010

Source: http://www.epa.gov/airtrends/2011/report/fullreport.pdf

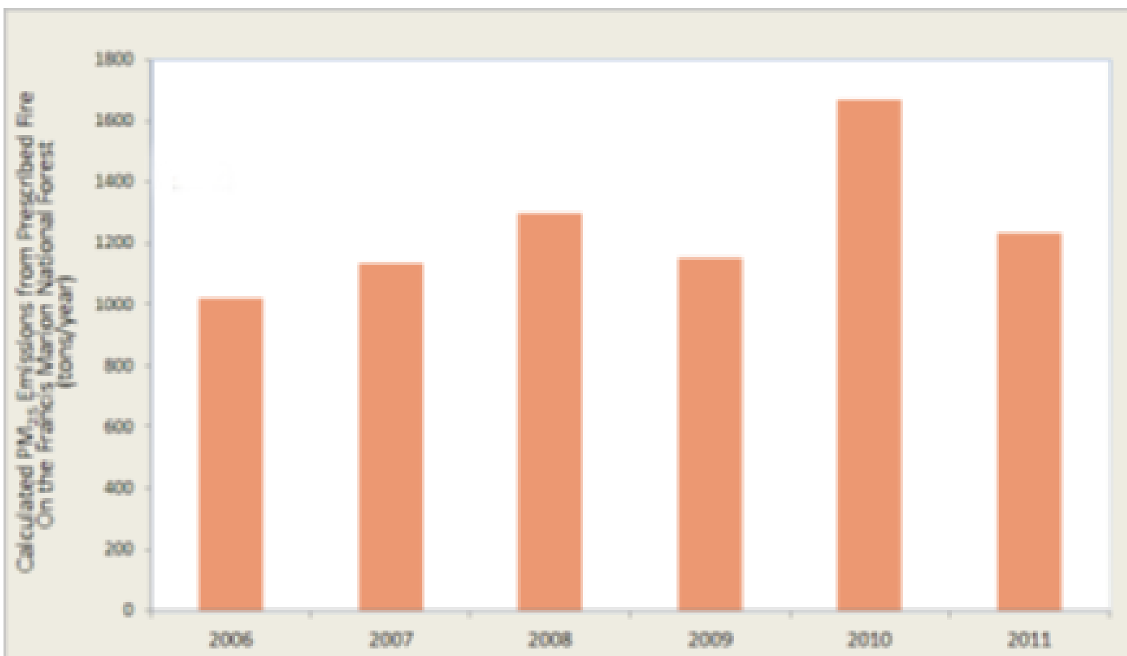


Figure 2-3. Emissions of fine particulate matter from prescribed fires on the Francis Marion National Forest, 2006–2011

Ambient Air Quality Trends

Ambient concentrations of air pollutants, including ozone and fine particulate matter, are measured by the South Carolina Department of Health and Environmental Control (SC DHEC) at locations near the Forest. Figure 2-4 displays the location of the monitoring sites used in this assessment. This includes ground-level ozone concentrations at two locations and fine particulate matter monitoring at two locations near the Forest. The measurements are compared to the appropriate NAAQS to assess whether air quality is healthy or not.

Figure 2-4. Location of ozone and fine particulate matter Monitoring

sites used in this assessment of air quality

Figure 2-5 shows the ozone concentrations at two monitoring sites close to the National Forest. The measured concentrations (blue open circles) for the years 2004–2012 are compared to ozone NAAQS (red line), and results are also given on the statistical trends. Ozone monitors near the Francis Marion National Forest have not exceeded the current ozone standard since 2005. Ozone levels appear to be fairly level, with no statistically significant trend either upward or downward. EPA is required to reassess the standards every 5 years based on most recent scientific research, and as a result more stringent standards may be proposed sometime in the future.

Figure 2-6 shows the fine particulate matter concentrations at monitoring sites close to the National Forest. The measured concentrations (open blue circles) for the years 2004–2012 are compared to both the daily (24-hour) and annual NAAQS (red lines). The monitors near Francis Marion National Forest have not exceeded either the daily or the current annual fine particulate matter standard since 2006. Levels of ambient fine particulate matter are experiencing a statistically significant downward trend over the same time period. As with ozone, EPA is required to reassess the standards every five years based on most recent scientific research, and as a result more stringent standards may be proposed sometime in the future.

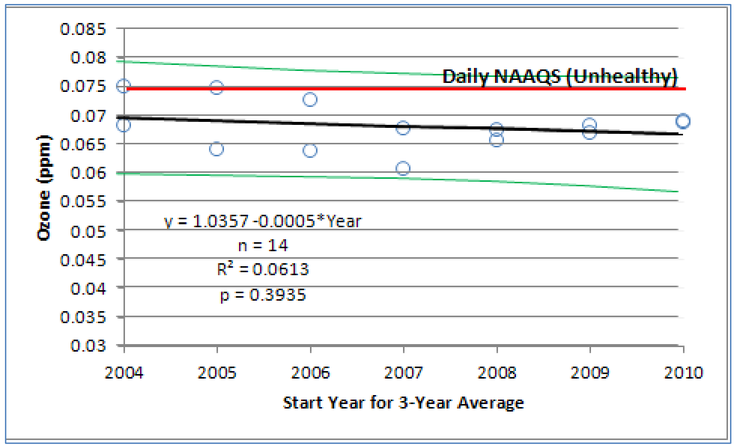


Figure 2-5. Statistical trend in ozone near the Francis Marion National Forest

Note: The blue open circles are the 3-year average of the 4th highest ozone concentrations at the monitoring sites in Berkeley or Charleston counties. The black line is the predicted values for ozone, while the green lines are the 95% confidence intervals for the estimate. The red line is the current National Ambient Air Quality Standard (NAAQS). The downward trend of ozone is not significant ($p > 0.05$). The unit of measure is parts per million (ppm).

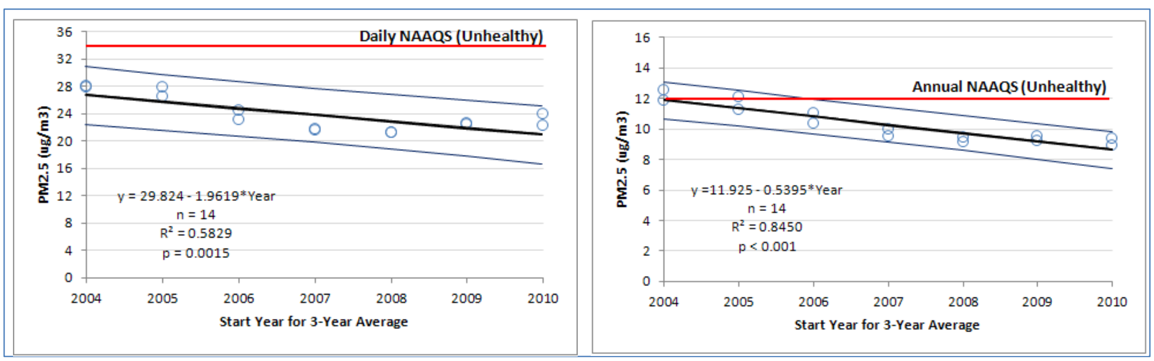


Figure 2-6. Statistical trends in fine particulate matter ($PM_{2.5}$) near the Francis Marion National Forest for the daily (left) and annual (right) National Ambient Air Quality Standard (NAAQS)

Note: The blue open circles are the 3-year average of the concentrations measured at the monitoring sites in Charleston County. The black line is the predicted values for ozone, while the blue lines are the 95% confidence intervals for the estimate. The red line is the current NAAQS. The downward trend in fine particulate matter is significant ($p < 0.05$). The unit of measure is micrograms per cubic meter (µg/m3).

Deposition of Sulfates, Total Nitrogen, and Mercury

Acidic (sulfur and nitrogen) compounds can be deposited from the atmosphere in a dry form (first seen as haze), in rainfall (wet), and in clouds or fog. Most of the deposition of sulfates and total nitrogen (nitrates and ammonia) on the Francis Marion National Forest occurs in the rain. The National Atmospheric Deposition Program (NADP) provides a long-term record of acidic deposition at sites located throughout the United States and monitoring of deposition has occurred on Cape Romain National Wildlife Refuge since the year 2000. The NADP acidic deposition data was combined with precipitation and other data to statistically estimate the Forestwide annual sulfate and total nitrogen deposition from rainfall for the years 1983 through 2011 (Grimm and Lynch 2004).

Sulfates are the most abundant acid compound deposited from the atmosphere and they continue to impact the soils on the Francis Marion National Forest. In 1983, the amount of sulfate deposition from the rainfall was greater than 12 kilograms per hectare (which is roughly equivalent to 12 pounds per acre) with the greatest deposition occurring in the northwest corner of the Forest. Sulfur dioxide (the precursor to sulfates) has decreased significantly since 1977 and the 2011 estimated sulfate deposition for most of the Forest was 9 kg/ha or less (Figure 2-7). Figure 2-8 shows that Forestwide annual average sulfate and total nitrogen deposition from rainfall has significantly declined between 1983 and 2011.

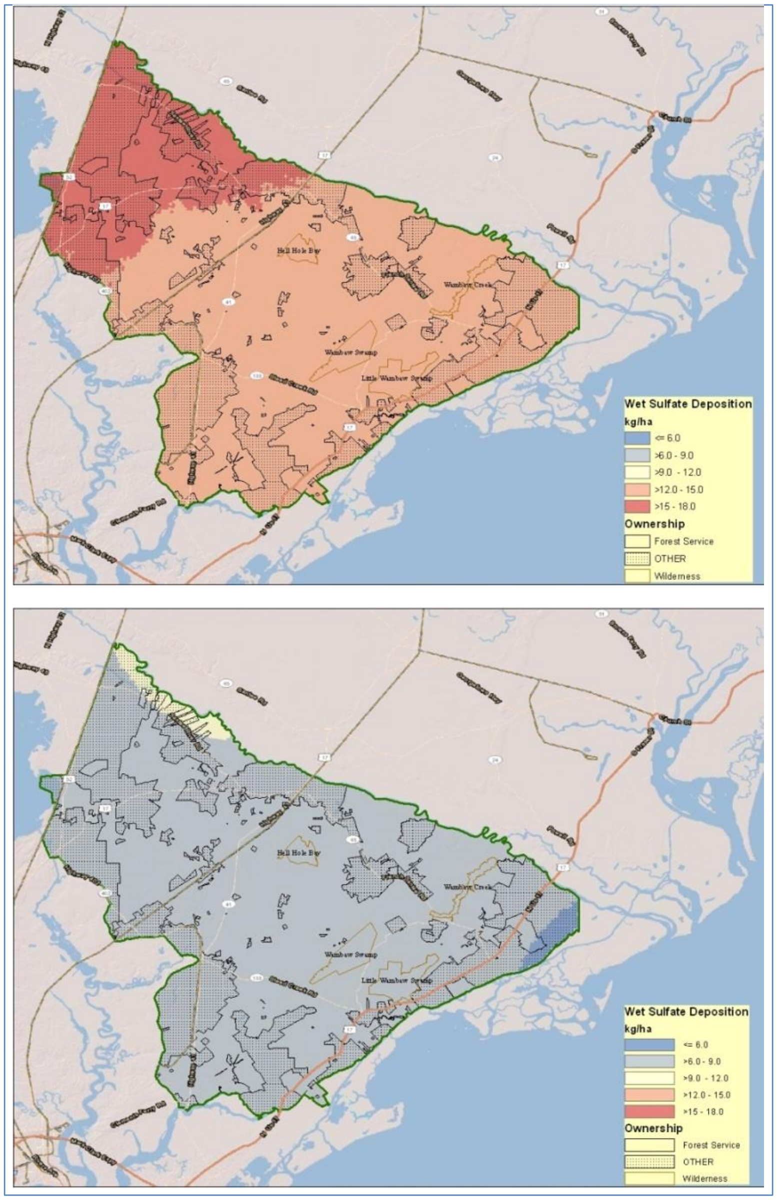


Figure 2-7. Estimated Forestwide wet sulfate deposition for 1983 (top) and 2011 (bottom) have shown a significant decline

Note: The unit of measure is kilograms per hectare (kg/ha). One kg/ha is approximately the same as one pound per acre. Deposition estimates based upon the approach used by Grimm and Lynch (2004).

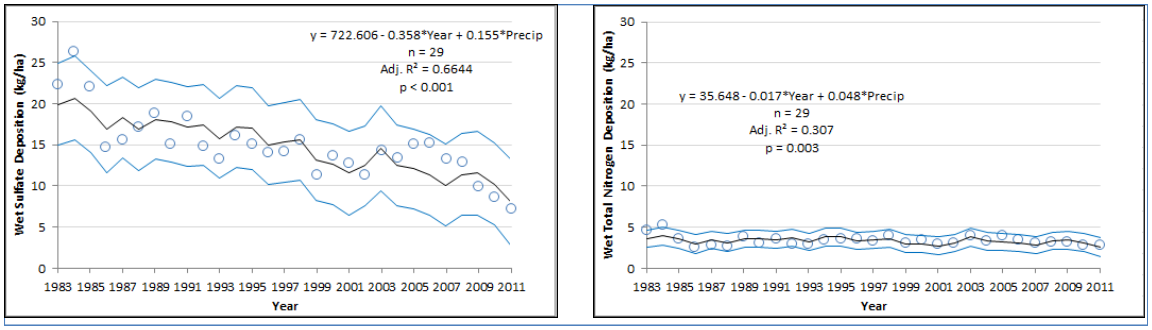


Figure 2-8. Trends in the average annual sulfate (left) and total nitrogen (right) wet deposition estimates (blue open circles) within the Francis Marion National Forest proclamation boundary

Note: From Grimm and Lynch (2004). The black line is the predicted wet sulfate or total nitrogen deposition, while the blue lines are the 95% confidence intervals for the estimates. The downward trend in wet sulfate and wet total nitrogen deposition is significant ($p < 0.05$). The unit of measure is kilograms per hectare (kg/ha). One kg/ha is approximately the same as one pound per acre.

Another air pollutant that can be deposited and have a negative impact on the ecosystem is mercury. Once mercury deposition occurs, it is often transformed by wetlands into methyl mercury (MeHg), which bioaccumulates in fish. Wetlands, which are found throughout the Francis Marion National Forest, are important sinks for mercury, as well as sources of methyl mercury. Fish consumption advisories are common throughout coastal South Carolina due to methyl mercury, as shown in Figure 2-9. The National Water-Quality Assessment Program (NAWQA) established by the U.S. Geological Survey found that the Santee Basin (which includes the Forest) has the highest methylation efficiency in the nation.

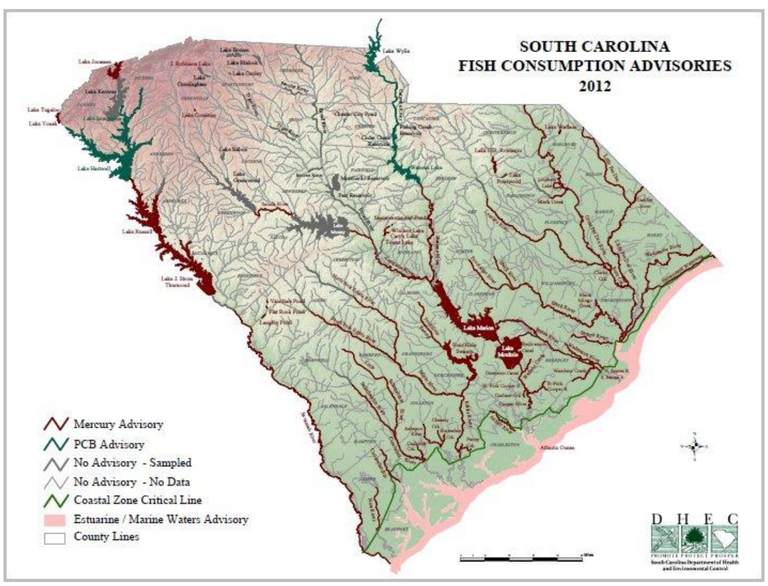


Figure 2-9. Fish consumption advisories in South Carolina

Source: http://www.scdhec.gov/environment/water/fish/docs/map.pdf

NADP operates the Mercury Deposition Network (MDN) which provides data on geographic distributions and trends of mercury in precipitation. MDN has operated a site on Cape Romain National Wildlife Refuge since 2004. Results from the monitoring (http://nadp.sws.uiuc.edu/mdn/) indicate that Cape Romain (and likely the nearby Francis Marion National Forest) receives more than 10 micrograms per square meter of mercury deposition.

In the past, South Carolina has recognized that many water bodies within the State, including those adjacent to the Francis Marion, do not meet state water quality standards for mercury (http://www.scdhec.gov/environment/water/tmdl/docs/tmdl_06-303d.pdf). More recently, SC DHEC has listed mercury as a 303d pollutant, but has not included the parameter of mercury when setting forth TMDLs, because procedures to deal with this pollutant have not been developed (http://www.scdhec.gov/environment/water/tmdl/tmdlsc.htm).

Site-specific Monitoring

As part of the "Wilderness Challenge," in 2011, an ozone biomonitoring project was implemented on the Francis Marion National Forest in four wilderness areas: Hell Hole Bay, Wambaw Swamp, Little Wambaw Swamp, and Wambaw Creek. The purpose of the project was to determine whether ozone exposures in the wilderness areas, as measured via symptoms, where causing a physiological response to sensitive vegetation. Nearby ambient monitoring data were also utilized to examine if ozone exposures could be causing biomass reductions to tulip poplar (an ozone sensitive species). The results of this project indicate that ozone is causing minimal impacts to sensitive vegetation occurring in these wilderness areas (Stratton 2011).

Other water inventories and assessments near the wilderness areas have focused on mercury and methylmercury in fish, rather than acid deposition. In 2003, Koman and Hanson reported on the status of water quality information on the Forest and focused on parameters such as fecal coliform, dissolved oxygen, conductivity and salinity, total mercury and methylmercury in fish, mud, and water (Koman and Hanson 2003).

Involvement with State Implementation Plans for Regional Haze

The USDA Forest Service is cooperating with the SC DHEC and other air regulatory agencies to identify air pollution emission reduction strategies to achieve natural background visibility at federally mandated class I areas. Additionally, the Forest Service has worked with the Regional Planning Organization (VISTAS) to ensure that emissions from Forest Service activities, especially prescribed fires, are included in the emissions inventories for the respective state implementation plans (SIPs).

Measurements of visibility-impairing pollutants are made at the IMPROVE (Interagency Monitoring of Protected Visual Environments) site located at Cape Romain National Wildlife Refuge, a federally mandated class I area, just to the east of Francis Marion National Forest. The IMPROVE monitor measures the concentration of different types of fine particles and these measurements are used to estimate visibility in deciviews. Each change in deciview is equivalent to a noticeable change in visibility; higher deciview values indicate hazier conditions, while lower values signify clearer air. The IMPROVE data are used to determine whether visibility is improving at the level required by the Regional Haze Rule. The Regional Haze Rule established a uniform rate of progress, also called a glide path, for each class I area to measure if enough progress is being made to meet natural background conditions by the year 2064. Figure 2-10 shows the 5-year average haziness index (light blue line) at Cape Romain National Wildlife Refuge increased above the glide path (pink line), but recently improved for the most recent 5-year average to match the glide path required by the Regional Haze Rule.

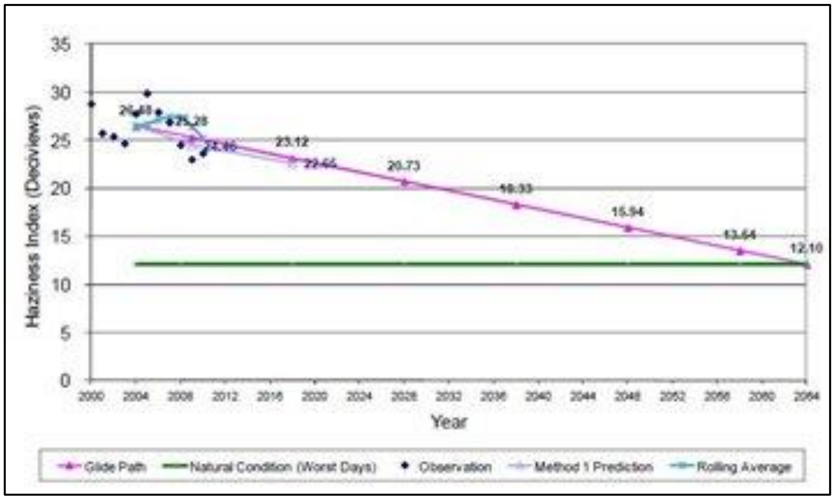


Figure 2-10. Measured visibility (worst visibility days) as compared to the glide path at Cape Romain National Wildlife Refuge Class I Area

Source: SC SIPR: Regional Haze Periodic Report

National and regional databases are weak at providing estimates of the amount of air pollution emissions from prescribed fires. To overcome this weakness, the USDA Forest Service assisted the VISTAS and the state air regulatory agencies by providing information on the time of the prescribed fires, location, and size of prescribed fires that occurred in 2002 and estimates for 2018. There were an estimated 23,962 blackened acres in 2002 and by 2018 the number of acres is projected to increase to 45,206 acres (Figure 2-11). The estimated number of blackened acres has been less than 45,000 acres between 2005 and 2011, except there were 50,569 blackened acres reported in 2010. Figure 2-10 shows the 2010 observed haziness index (blue dot) was below the glide path, which indicates the higher than projected blackened acres from prescribed fires in 2010 did not impede the regional haze goal at Cape Romain National Wildlife Refuge.

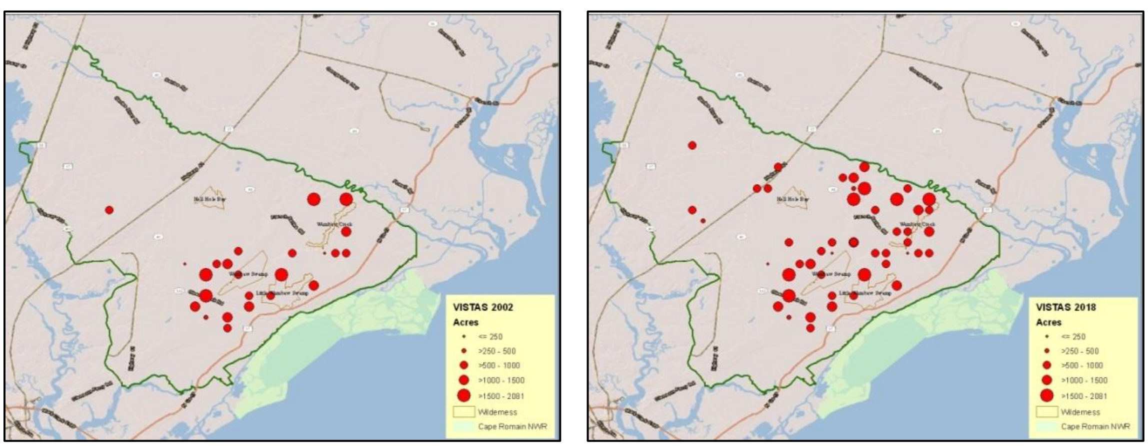


Figure 2-11. Location of prescribed fires in 2002 and those planned for 2018 on the Francis Marion National Forest

Note: The data was utilized in an atmospheric dispersion modeling analysis to evaluate if visibility at Cape Romain National Wildlife Refuge is predicted to improve by 2018.

Critical Loads for Soil Acidification on the Francis Marion National Forest

Many people are concerned that acidic deposition has and will continue to severely impact the health of terrestrial and aquatic resources. The deposition of sulfur and nitrogen compounds from the atmosphere can accelerate the loss of base cations (calcium, magnesium, and potassium) from the soils. Adequate supplies of base cations are needed in the soil to maintain healthy forests. One question that may be asked: Is the current sulfur and nitrogen deposition exceeding a level where no harm is likely to occur to sensitive components of the ecosystem? The total amount of sulfur plus nitrogen deposition that can be tolerated is called a critical load and it can be established to protect forest soils and/or sensitive biota. Current scientific knowledge is to be used when establishing critical loads for acidification. Estimates developed by McNulty et al. (2007) are being used in this assessment to identify if acidic deposition on any areas on the Francis Marion National Forest is exceeding the critical load.

McNulty et al. (2007) calculated the steady state critical load by obtaining spatial information for the Francis Marion National Forest. Estimates for some of the information needed included:

1. The annual amount of base cations (calcium, magnesium, potassium, and sodium) deposited from the atmosphere.

2. The base cation (calcium, magnesium, and potassium) weathering rate based upon the percent clay in the soils, and the parent geology.

3. The amount of base cations and nitrogen removed from a site when periodic timber harvesting occurs.

4. The amount of inorganic nitrogen deposited from the atmosphere that is converted to organic nitrogen in the soils.

5. The average annual runoff based upon data collected between 1951 and 1990.

6. The critical base cations to aluminum ratio that was set to 1.0 for conifer forests and 10.0 for deciduous forests.

The information obtained for these variables, along with others, were used in an equation to estimate the forest soil acid load. McNulty et al. (2007) subtracted the forest soil acid load from the average (1994–2000) annual acidity deposition estimates (sulfur plus nitrogen). Values that were zero or a negative number means the deposition of acids from the atmosphere did not exceed the calculated forest soil acid load; whereas values above zero indicate the average acidic deposition exceeds the amount the soils can buffer to maintain the long-term health of the ecosystem. Table 2-2 and Figure 2-12 show the acidic deposition does not exceed the critical load for most (64 percent) of the area within the proclamation boundary. This is expected because large portions of the Forest soils are derived from limestone or other carbonate sources (Cameron and Martin 1984), which account for the high presence of base cations in the soils. About 25 percent of the soils are being impacted by total acidic deposition above the critical load and most (15 percent) is Forest Service ownership. Figure 2-12 shows that acidic deposition has been significantly decreasing since 2000. Calculations performed for this assessment estimate that there may have been an additional annual average reduction of 96 equivalents per hectare per year (eq/ha/yr) between 2005 and 2011 when compared to 1994 to 2000. Even with this reduction there will still be at least 18 percent of the area where the acidic deposition is exceeding the critical load.

Table 2-2. Percentage of ownership in each of the soil acidic deposition critical load exceedance categories based upon McNulty et al. (2007)

Acidic Deposition Exceedance	Ownership (%)		
	Forest Service	Other	Total
No Exceedance	43.23	20.87	64.10
0–250 eq/ha/yr	4.17	2.62	6.79
250–500 eq/ha/yr	11.17	7.01	18.18
No Estimate	3.68	7.25	10.93

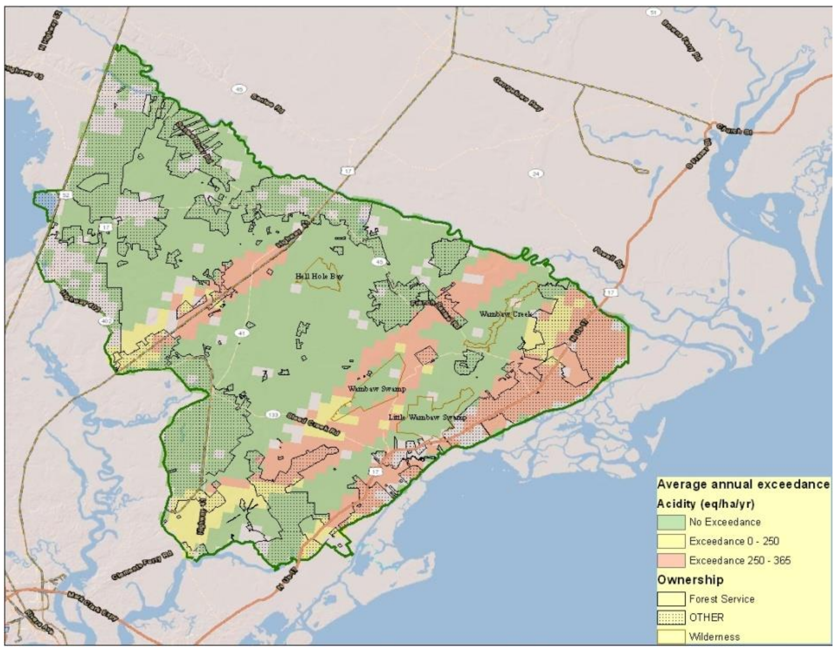


Figure 2-12. Areas (yellow or red) where the average (1994–2000) atmospheric sulfur plus nitrogen deposition exceeds the soils critical loads

Note: Spatial data following McNulty et al. (2007); the units of measure are equivalents per hectare per year (eq/ha/yr).

Caution should be used when interpreting these critical load exceedance results. First, McNulty et al. (2007) were providing initial estimates for the conterminous United States to "… locate forest soil areas that could potentially be in exceedance of the…" critical load. Second, the deposition of sulfur and nitrogen compounds has decreased since the McNulty et al. (2007) was completed. Finally, steady state critical loads do not take time into consideration; although critical load exceedances indicate the potential for ecosystem damage, this damage may not be currently ongoing, and may not occur for centuries. Therefore, establishing an acidic deposition target load is not recommended for the Francis Marion National Forest, until further soil sampling and other site-specific measurements are conducted within the areas (Figure 2-12) identified as exceeding the critical load. The critical load exceedances calculated by McNulty et al. (2007) can be used to develop monitoring plans to verify critical load exceedance calculations.

2.2.1.4 Information Needs

The review of current conditions and trends on the Francis Marion National Forest shows that mercury deposition may be having an effect on both water and aquatic fauna, although SC DHEC's decision to not include mercury as a parameter in recent listing of impaired waterbodies may indicate that the situation is improving. At the same time, several of the blackwater areas on the Forest are affected by fish-consumption advisories due to mercury. However, measurement of mercury and its impacts are expensive and require exacting sampling techniques most appropriately done in conjunction with research scientists. At this time, the Forest Service has not adopted a standard protocol for measuring and monitoring the effects of mercury, and therefore, specific recommendations on monitoring the effects of mercury have not been made. Considering the impact mercury deposition might be having, the Forest may want to look for additional opportunities to partner with the State or a research group to measure impacts on Forest Service ownership, especially any which are dominated by wetlands.

An initial estimate suggests that about 15 percent of the Forest Service ownership on the Francis Marion National Forest is exceeding critical loads of acidity, indicating the potential for harm to sensitive components of the ecosystem. However, the results in this assessment should not be used to establish a target load. Instead, further soils and other data collection should be obtained and used in an ecological model to estimate more precisely when unacceptable impacts are likely to occur, and what level of acidic deposition can be tolerated so there are no impacts to forest soils and/or terrestrial or aquatic biota.

2.2.2 Soil

2.2.2.1 Preliminary Findings

►According to existing soils data, nearly 56 percent of the Forest is considered to be hydric (see Figure 2-13). Hydric soils include: poorly drained and very poorly drained.

►A large portion of hydric soils have had some type of drainage modification. The extensive hydrologic modifications across the landscape were not always evident in past soil mapping activities. Some changes in soils may have resulted from the past drainage, diking, and associated activities that will be only evident at project- or site-level inspections.

►Soil classification could have changed in some areas, mainly in bays and swamps, due to high fire burn severity.

►Monitoring of soils was not addressed in the 1996 Forest plan and would not meet requirements in the 2012 Planning Rule. In order to track changes to the soil resource in the future more effort needs to be made to complete the USDA Forest Service soil quality monitoring process (USDA Soil Management Manual 2010).

►New information, such as LiDAR, is now available and is being used to update the soil map for the Forest. This update will create more precise soils maps that can be used to analyze impacts from site-specific projects.

►Ruts from past harvesting operations including post-Hugo salvage are prevalent across the landscape. Depending on the severity, these ruts likely interrupt local surface and subsurface hydrology.

2.2.2.2 Existing Information

Direction in the Francis Marion Forest plan is found in different sections:

Desired Future Conditions (page 1-5, Francis Marion Forest plan). “Soil productivity is maintained. Soil quality and nutrient cycling processes are maintained. Large woody debris, leaf litter and other organic matter are retained on many areas to fulfill an important ecological role in providing soil organic matter, plant nutrients, and energy for soil micro-organisms. Soil structure is maintained except for areas such as construction sites, roads, skid trails and some log landing areas.”

Forest-wide standards are included in chapter 3 of the 1996 Francis Marion Forest plan. Some Forest-wide standards to protect soils are included here, but see the 1996 Forest plan for a complete list:

- FW-101 Avoid construction (roads, trails, recreational sites, etc.) in floodplains and wetlands whenever there is a practical alternative.
- FW-102 Restore primary skid trails and log landings on soils with sandy loam to clay textures within 10 inches below soil surface (i.e., smooth out and fertilize primary skid trails and fertilize log landings) to minimize loss of soil productivity and water quality as needed.
- FW-103 Install adequate road drainage structures to provide for normal surface water movement.
- FW-105 Locate skid trails, log landings, and log ramps on wet sites and riparian areas according to the following criteria, and only as designated by a Forest officer.

  a) Locate permanent log landings on elevated terrain generally at 0.5-mile intervals.

  b) Limit concentrated skid trails and log landings to no more than 10 percent of an area so that compaction and other disturbance will be contained to only those areas disturbed.

  c) Construct log ramps on the best drained sites to facilitate access to log landings from system roads and to minimize skidding distance.

  d) The number of log landings will be the minimum needed to harvest any area.

- FW-106 Prevent and minimize the effects of soil compaction, rutting, and puddling during activities through the use of low ground pressure equipment, aerial systems, activity suspension or other soil protection measures as mats, bridges, woody fill, etc., when saturated or wet soil conditions cannot be avoided. Indicators that may signal caution include (1) the water table within 18 inches of the surface; (2) difficulty in walking across the site without compacting, seeing or hearing surface or groundwaters under foot; (3) presence of wetland indicator plant species, hydric soils and/or saturated or flooded hydrologic conditions during activity, and (4) events which flood or saturate soils.
- FW-107 Avoid direct application of fertilizer to water bodies including streams (unless prescribed for wildlife habitat improvement).

The Forest has developed an agreement with the Natural Resource Conservation Service (NRCS) in South Carolina to update the Francis Marion National Forest soil maps. Through the agreement, parties will also install water wells on the Francis Marion in order to monitor shallow water table levels which will aid in forest management recommendations. Collaboration between the Forest and the NRCS is expected to continue for years to come.

Forest managers collaborate with researchers from the Santee Experimental Forest on issues related to watershed management.

2.2.2.3 Current Condition

Soil is a collection of natural bodies that consists of organic matter, minerals, living organisms, and is capable of supporting a wide variety of biological, chemical, and physical processes. Soil is a result from the weathering of parent material over extended periods of time. Physical components of soil include various sizes of a mineral component, organic matter, water, and air.

The Forest lies within the Sea Island section of Atlantic Coastal Plain Physiographic Region. Soils of this region have formed in marine and fluvial sediments that were deposited during the Quaternary period and are Pleistocene in age (SCDNR). Within the Francis Marion soils may encompass any given percentage of organic matter, sand, silt, and clay which may occur in various combinations and depths. Soil horizon development has been influenced by climate, living soil organisms, and relief. Also, soils within the Forest have been influenced overtime by cultural alterations. For instance, dikes and dams used to flood rice fields have altered the hydrology of the area, which in turn affected soil development and quality.

A 2nd order soil survey has been used to delineate and identify specific soil series and their boundaries within the Forest. At this level the minimum mapping unit typically ranges from 2 to 8 acres, so local inclusions of other soil types within a mapping unit may be found. Currently, there are 77 map units identified on the Forest (SSURGO 2013). Landforms in which these map units occur on include ridges, marine terraces, Carolina bays, swamps, pocosins, depressions, flats, and floodplains. Elevations of these landforms range from 5 below to 81 feet above sea level. Drainage class of these soils range from excessively well drained to very poorly drained.

Soil function is ecosystem-specific and must be assessed in the context of desired ecological condition (Burger et al. 2010). Eighteen ecological systems have been identified for the Forest plan revision (Simon and Hayden 2013). Due to the lack of soil quality data for each of these ecological systems and since soil types, their properties, and processes vary greatly, a comprehensive assessment of soil quality has not been possible and contributes uncertainty. Also, some management goals may not be completely complementary with respect to soil quality; one goal may, in fact reduce soil quality for another goal. Therefore, an assessment of soil quality and current conditions are discussed in general.

Soil quality has been defined as its ability to provide services important to people. It is useful as a measure of the extent to which a managed soil is improved or degraded from its natural state or some other selected reference condition (Burger et al. 2010). Although there is no data to compare soil function today to its function in a natural setting; overall soil quality within the Forest is considered to be adequate. However, soil quality may be less than adequate for the current desired condition in some areas due to soil disturbance from past land management practices.

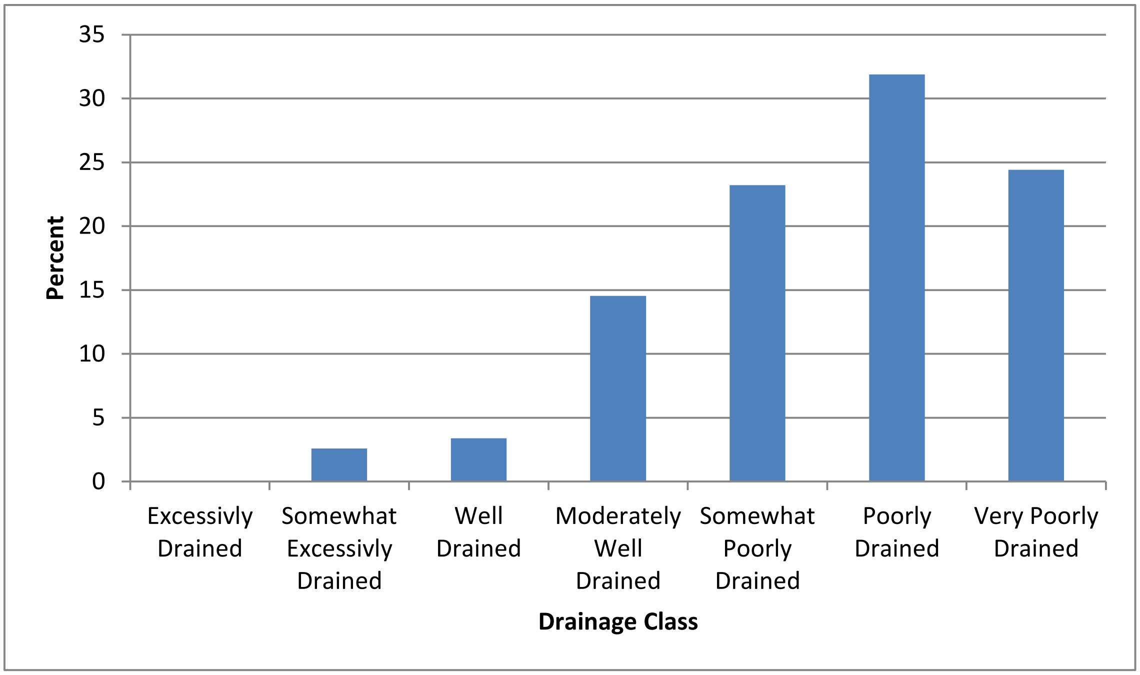


Figure 2-13. Drainage class distribution for soils within the Francis Marion National Forest

Past land management practices have most likely altered soil hydrology more than any other soil attribute. Throughout the Forest water tables are typically close to the surface and soils with restricted drainage are common (NRCS 2010a). Many areas with these characteristics show signs of skid roads, rutting, compaction, and soil displacement. These areas are the remnant effects of the Hurricane Hugo salvage and other past operations that occurred when conditions were unsuitable for the use of mechanical equipment. The portion of these areas that were compacted and rutted now holds water for extended periods of time. Alterations to soils have been found to occur more frequently on hydric soil types, which comprise approximately 56 percent of the total land area of the Forest. A large portion of hydric soils has had drainage modifications that include channelizing streams, drainage ditches, and forestry bedding.

In general, soils have not changed very much since the last Forest plan revision. There are localized changes due to management activities that disturb the soil surface, but generally changes in soil properties are more static. Occasionally, during dry weather patterns, wildfires and some prescribed fires enter into areas that are normally wet and burn several inches of accumulated organic material. Depending on the degree of change, soils in those areas function differently than before the fire and may also be taxonomically different. These changes are not regularly monitored or documented except in some wildfire instances where a damage assessment associated with a burned area emergency response report was completed.

Overall, most soils are adequately fertile; however, the poorly drained soils have low fertility levels and hydrous oxides of iron and aluminum that cause some restrictions on pine tree growth. Soils within the Forest are stable with little erosion occurring across the area.

Soils are intact and serve as a medium for root growth and soil organisms. Soil organisms are vital to decomposition and cycling of plant and animal materials in soils; however, the exact role of soil biological communities in maintaining soil quality is unclear (Levi 2007). The rapid carbon assessment done by the NRCS show soil organic carbon stocks are considered to be between 1,001 to 1,200 mg/ha to a depth of 100 centimeters (soil survey staff, RaCA project). In forest soils, nutrient supply and biological activity are intimately tied to organic matter and nutrient cycling processes, including rates of input, decomposition and mineralization, storage, and release or uptake. Protection of these processes from soil surface disturbances, displacement of soil organic matter layers, and severe burns should maintain function in a given soil of a certain ecosystem.

2.2.2.4 Information Needs

The current soil map for the Forest is being updated and should be finalized during 2014. Also, an ongoing soil updating process will be needed in the future. As the technology changes and the Forest incorporates new information, such as LiDAR, soil maps will become more precise.

In order to track changes to the soil resource in the future, more effort needs to be made to complete the soil quality monitoring process.

2.2.3 Water Resources and Quality

2.2.3.1 Preliminary Findings

►Information sources suggest blackwater streams with headwaters in wetland areas produce methyl mercury through sulfate reduction. Methyl mercury can bioaccumulate and has contributed to fish consumption advisories in certain predatory fish species (Plewa and Hansen 2003; SC DHEC 2012; SCDNR 2013). Other connected species that feed on aquatic organisms from blackwater streams may also be affected according to some sources (Wikipedia 2013). The SCDNR 2013 fish consumption advisory map identifies the main streams, but smaller streams are suspect.

►Water quality total mean daily loads (TMDLs) have been identified for action for fecal coliform and methyl mercury on select stream systems with the watersheds on the Francis Marion National Forest. Fecal coliform is a particular concern within the tidal shellfish gathering waters. Feral pigs are an introduced source of fecal contamination that could be influenced by continued treatment by the Forest Service. It is uncertain how much Forest management activities and the legacy of hydrologic modifications has contributed to the movement of fecal coliform and methyl mercury within the forest environment. The State of South Carolina may need to work with Forest personnel on corrective actions, but no actions have been indicated at this time.

►Salt or brackish water influences are known along the Santee River and lower tributaries due to the low flow periods from the Santee Cooper Dam Project, particularly during high tide periods with new and full moons, high eastern winds, tropical or hurricane winds (Hansen 2008). In addition to this, sea-level rise may influence about 4 to 5 percent of the Forest with habitat type changes over the next 50 to 100 years, using the A2 model maximum extent that addresses a 0.74 meters (30 inches) sea level rise over 100 years. The limit of the various models over the 100 year period is 2 meter increase in sea level. The model also considers erosion and accretion of land as a result of the increased tidal influence. Most of the changes are undeveloped upland forest to shrub/scrub transitional marsh (TACCIMO-SLAMM 2013). These conditions of sea level change have a substantial degree of uncertainty as to their extent, but will locally impact instream water quality and have the potential to modify aquatic, marsh, maritime and freshwater habitats. More detail is discussed in the climate change section.

▶The stream network, location, permanence of flow indicators, and channel type based on existing mapping should be updated for the Forest plan revision. Improvements based on LiDAR are forthcoming. A degree of uncertainty will remain with the application of the newly derived data, but the improved outputs will be more consistent with field conditions.

▶In comparing reference, desired, and existing condition, past hydrologic modifications have altered stream, riparian and wetland conditions. The majority of the hydrologic modification included drainage or impounding for agriculture. Little direction was mentioned in 1985 or 1996 plans or limited analyses about effects of past actions relative to altering hydrology. It is uncertain about how much impact these modifications continue to have on water flows, aquatic habitats, riparian areas, and other resources. There have been no efforts to determine their impact or diffuse their effectiveness. It is unlikely that they would naturally restore themselves and the assumption is they continue to modify the hydrology. This lack of information is a gap in knowledge, but the plan will consider and include the potential for hydrologic restoration to benefit forest resources.

▶Limited direction was mentioned in earlier Forest plans about tidal areas, which include tidal swamps, salt or brackish marsh, transitional marsh and estuary. TACCIMO-SLAMM suggested there are about 8,000 acres that have some degree of tidal influence in the next century. This estimate may not include the full extent of effected areas in the Santee River and tributaries such as Wambaw Creek. About 5,000 acres may be influenced in sea-level rise over the next 50 years. Hydrologic modifications complicate and add uncertainty. Added attention to tidal areas and critical habitats may be warranted in the plan revision. Outside funds may be available to help restore critical habitats and streams which have been affected.

▶Hydrological modifications may have altered the hydration of riparian areas and wetlands. As a result, vegetation types, fire regime, fuel hazard, and their natural ability to serve as fuel breaks or protective buffers from development within the urban interface may have been reduced. Retaining large wood in streams depends on saturation, limited fire, and a continuing source of new wood. Conditions that favor rehydrating the floodplain and encouraging large wood entry into stream systems may help retain large wood and improve stream permanence. Besides benefits to water quality and aquatic habitats, there may be benefits to provide a more natural fuel break between Forest and private lands.

▶The 1996 plan did not recognize the effects relative to the Intercoastal Waterway, major dams, channel dredging of Cooper River, former dredging to improve access to tidal areas, or similar activity within the area immediately adjacent to the Francis Marion National Forest. Some of these actions are history, and some are ongoing with respect that they are periodically maintained. There is a degree of uncertainty relative to extent and degree these outside activities have affected the Forest.

▶Nationwide efforts for the development of National BMPs (best management practices) are in various stages of development and implementation. The new National BMP Program consists of four components: (1) the National Core BMP Technical Guide (Volume 1; FS-990a, April 2012); (2) the National BMP Monitoring Technical Guide (Volume 2; FS-990b, in development); (3) revised national directives in FS Manual and Handbook; and (4) a national data management and reporting system. The National Core BMP Technical Guide (Volume 1) was published in 2012 and the National BMP Monitoring Technical Guide (Volume 2) expected in 2013. The revised directives are needed to provide clear direction for implementation of the National BMP Program and would allow the Forest Service to address implementation of the National BMP Program on its lands in a consistent manner. The proposed directives require the Forest Service to implement the National Core BMPs, conduct implementation and effectiveness monitoring, and report on and evaluate monitoring results.

However, at the state and Forest levels, since SC BMPs for Forestry were developed in 1994, management measures in the Coastal Zone Management Act, the 1996 Francis Marion plan standards and guidelines, and the 2002 Region 8 Soil and Water Conservation Practices Guide have been guiding Forest operations. South Carolina Forestry Commission and Forestry Association, in cooperation and support from industry, Clemson University and the US Forest Service have intended to set an industry standard by designing and implementing BMPs to protect water quality, beneficial uses of water and as needed, provide stewardship-based information including measures needed to conserve soils, wetlands, streams, wildlife habitat and fisheries. Under most circumstances, industrial forest mills require loggers to obtain BMP certification in order to market wood products. Ultimately, implementing and monitoring effectiveness of the Forestry BMP program helps to insure that water resources are adequately protected in logging and other forestry management activities. By practicing BMP stewardship, the public importance and benefits of managing forests to produce quality water to support beneficial uses such as aquatic habitat, recreational uses, as well as development and growth. Based on periodic monitoring, South Carolina has realized a high degree of BMP implementation, and the intent is to continue to use this program to limit the effects of silvicultural and harvesting practices on water quality. BMP design and implementation appears to be a better way to prevent water quality impacts and conserve associated resources than setting and enforcing outside rules and regulations that may not fit South Carolina or the timber industry circumstances.

▶Since 1996, additional direction to monitor a wide variety of ground-disturbing and other activities with the potential to impact water quality has been developed. This direction includes the National BMPs (USDA Forest Service 2012), the BMPs previously mentioned. Consistency with BMP direction in the 1996 Forest plan was an important element. BMP compliance checks on Forest activities suggest that BMPs are being implemented and water quality is being sufficiently protected from ground disturbance (Adams and Hook 1993; Adams 1994, 1996; Jones 2000, 2005; Sabin 2006, 2009, 2012). However, with the poor delineation of streams and riparian areas, there remains some potential that projects may not always have all the information needed and must rely on field delineations and checking to be sure resources are adequately protected. Availability of LiDAR products has the potential to improve ability to identify streams, riparian areas, and ditches in project planning.

▶Surface water, riparian, wetland, and groundwater connectivity was not discussed in the 1996 Forest plan. These connections are evident, but not well defined or understood as to what those implications may be to the Forest plan and management activities. However, we do know that certain activities such as groundwater removal, material borrow or mining, roads, and hydrologic modifications may have effects which need consideration within the Forest plan.

2.2.3.2 Direction in the 1996 Francis Marion Forest Plan

Chapter 3 in the 1996 Francis Marion Forest plan contains Forestwide standards designed to protect water quality from management activities, such as herbicide application, timber harvesting, and other ground-disturbing activities. This list is not all inclusive, but just a highlight of some relevant Forestwide standards:

> **FW-101** Avoid construction (roads, trails, recreational sites, etc.) in floodplains and wetlands whenever there is a practical alternative.

FW-102 Restore primary skid trails and log landings on soils with sandy loam to clay textures within 10 inches below soil surface (i.e., smooth out and fertilize primary skid trails and fertilize log landings) to minimize loss of soil productivity and water quality as needed.

FW-103 Install adequate road drainage structures to provide for normal surface water movement.

FW-104 Fertilize sites according to guidelines specified in the Forest Fertilization and Soil Productivity Improvement Guide (on file in the planning records in the Forest Supervisor's Office in Columbia, South Carolina).

FW-105 Locate skid trails, log landings, and log ramps on wet sites and riparian areas according to the following criteria, and only as designated by a Forest officer.

a) Locate permanent log landings on elevated terrain generally at 0.5-mile intervals.

b) Limit concentrated skid trails and log landings to no more than 10 percent of an area so that compaction and other disturbance will be contained to only those areas disturbed.

c) Construct log ramps on the best drained sites to facilitate access to log landings from system roads and to minimize skidding distance.

d) The number of log landings will be the minimum needed to harvest any area.

FW-106 Prevent and minimize the effects of soil compaction, rutting, and puddling during activities through the use of low ground pressure equipment, aerial systems, activity suspension or other soil protection measures as mats, bridges, woody fill, etc., when saturated or wet soil conditions cannot be avoided. Indicators that may signal caution include: (1) the water table within 18 inches of the surface; (2) difficulty in walking across the site without compacting, seeing or hearing surface or groundwaters under foot; (3) presences of wetland indicator plant species, hydric soils and/or saturated or flooded hydrologic conditions during activity; and (4) events which flood or saturate soils.

FW-107 Avoid direct application of fertilizer to water bodies including streams (unless prescribed for wildlife habitat improvement).

FW-109 (R8–VM) In each project, water quality is protected from nonpoint-source pollution through use of preventive "best management practices" (BMPs). Implementation of BMPs, monitoring and evaluation of their application and effectiveness, and adjustment of practices as needed are done to protect beneficial water uses and comply with State water quality laws. BMPs are applied to all activities. In each project, site-specific conditions must be assessed, and the BMP's needed to meet state water quality standards must be employed.

FW-115 Maintain a near continuous (unbroken) canopy of vegetation for 30 feet on both sides of perennial streams and water bodies. Resource management activities may be implemented if riparian conditions are maintained or improved and the natural supply of large woody debris into the streams and water bodies is not impaired. Timber harvest methods that ensure a residual basal area of 50 percent can be utilized when managing a zone from 40 to 70 feet on perennial streams and water bodies and 40 feet on either side of intermittent streams. Use of mechanical equipment will be limited to protect the riparian and water resources. Additional zones adjacent to riparian areas and ephemeral streams can be established as necessary to meet site specific conditions and management objectives. The width of the zones will depend on slope, vegetation and soil conditions. These zones will be managed to protect soil and water resources by the types of management activities in these zones and controlling the use of equipment.

Although more recent than the 1996 Forest plan, the Southern Region Guide for Soil and Water Conservation Practices is also consulted as needed in the attempt to apply the combination of practices that protect water quality and limit effects (McLaughlin et al. 2002).

Desired future conditions identified in the Forest plan did identify the need for streams, ponds, wetlands, and riparian areas of the Forest reflect healthy, functioning ecosystems. However, due to limited information at that time, the primary assumption was that implementing BMPs and Forest Standards would be sufficient to do this. As a result, there was no specific or special measures identified in the objectives to improve conditions.

2.2.3.3 Introduction

Water resources are an important aspect of National Forest conservation and management. All life has some water dependency from the very basic cell makeup, providing moisture to maintain complex plant and animal needs, or to scenic beauty and water-based sports. Sedell et al. (2000) provide an excellent oversight document for "Water and the Forest Service", discussing its various aspects and importance of water to the Forest Service mission.

With the oversight and approval of Environmental Protection Agency (EPA), the South Carolina Department of Health and Environmental Quality (DEHC) address and regulate water resources within their authority. DHEC is responsible for setting guidance and regulations to ensure South Carolina's surface, ground, and drinking water resources meet State water quality standards. DHEC's website has numerous water quality related reports, documents, maps, links to regulations, peer-reviewed literature, and brochures. The South Carolina Forestry Commission has been authorized to oversee the development, implementation, and monitoring of practical measures that avoid, limit or mitigation the effects of forestry activities as described in the SC Forestry Best Management Practices (BMPs) Manual. More about Best Management Practices will be discussed later.

In addition, other resource agencies and nonprofit organizations such as SC Department of Natural Resources (DNR), Army Corps of Engineers (ACOE), U.S. Fish and Wildlife Service (USFWS), Natural Resources Conservation Service (NRCS),U.S. Geologic Survey (USGS), SC DHEC, Coastal Council, SC Coastal Conservation League, National Oceanic and Atmospheric Agency (NOAA), Clemson University, University of SC, College of Charleston, City of Charleston, Charleston and Berkeley counties and others have collected information, conducted studies, and evaluated conditions relative to many coastal water and environmental topics.

The USDA Forest Service Southern Research Station (SRS) has been a leader in addressing many of the hydrological and other resources of southeastern forests. Within the Francis Marion, the Santee Experiment Station is directed by SRS, conducts forest- and hydrologic-based research, collaborates with many other agencies and technical peers, and contains the national hydrometeorological station conducting research on coastal ecosystems. Many of these studies are referenced in the content.

Another nearby coastal research center and collaborator with hydrological research is Belle Baruch-Hobcaw Barony, where cooperative research is conducted by Clemson University, University of South Carolina, and others. The USGS College of Charleston, ACOE, and others have been important SRS partners in the Turkey Creek and groundwater studies. Adjacent coastal states also have research and hydrological information that may apply to coastal ecosystems of the Forest. North Carolina has collected substantial information and conducted analyses on hydrological conditions and many examples of minimizing, stabilizing or restoring modifications and land use alterations (Russell 2013). It would be extremely difficult to interject all of this information into forest planning and land management, and that is where some of the external peer review and agency collaboration helps insure that meaningful or critical information has not been overlooked in this process.

Beyond this, one may note the presence of historical information or references that provides added context to what is prepared. Substantial efforts to utilize Forest GIS and LiDAR information should be evident in this assessment.

2.2.3.4 Hydrologic setting

Reference condition is an interesting, but often unappreciated topic with respect watershed, hydrological, and aquatic conditions. Conditions were substantially different before the nonnative human influences that began about 500 years ago. This period of time is contained within the Little or mini-Ice Age, which was a more humid, cooler period about 150 to 650 years ago, with internal colder or warmer weather cycles during this period of time (Kemp et al. 2011; SCDNR 2013). Sea levels were about 2 feet lower. Beaver were abundant in the pre-Columbian era, but were trapped out by the 1700s (Logan 1859). This period was before roads, dams, dikes, railroads, drainage ditches, stream channelization, rural and urban development, air pollution from burning coal, etc. These modifications directly or indirectly helped drain or fill wetlands, control flooding, limit tidal influence, and modify, straighten and/or enlarge channels to "improve drainage" (SC Regulations, 1911-1962, Berkeley County et al. 1963; Trettin et al. 2008). Early history may have less runoff, more flooding, greater hydroperiods, more wetlands, higher evaporation, increased hydration of floodplains, and increased stream permanence (Schumm et al. 1984).

The result would be a wetter landscape, perhaps with increased bottomland and wetland forests. Primary disturbance regimes under reference conditions are natural variability in intensity, frequency, and disturbance from fire, flooding, and severe wind. The low gradient characteristic of most of the topography, the stream morphology, was most likely sinuous stream types such as Rosgen DA (braided-anastomosed) and Rosgen E types (Rosgen 1996) (see "Stream and Aquatic Extent, Types and Classification [Rosgen]" subsection under "2.2.3.5 Existing Condition and Information" for more information on Rosgen stream classification). The low gradient channels were further stabilized with vegetation types adapted to saturation and flooding with extensive rooting density that provided highly resilient and stable stream channels. The presence of Rosgen G (gully) type may be found on higher gradient stream sections characterized by entrenchment into the sand-dominated materials of the coastal landscape.

2.2.3.5 Existing Condition and Information

Note: This section includes hydrologic cycle rainfall, evapotranspiration, water flows, deep seepage, and associated background history.

Current conditions indicate an average water balance for the SC coastal plain of 50 inches of rainfall, 30 inches of transpiration, 10 inches of evaporation and 10 inches of runoff, with a minor part lost to deep seepage, perhaps 1 inch. These are general approximations that may vary with the land use and conditions, as well with year-to-year rainfall variation. Many of the coastal watershed boundaries are not well defined, adding some uncertainty and error to reported amounts. Some of the past studies have been reanalyzing with improved spatial detail such as LiDAR based DEMs (Amatya et al. 2012, 2013). Substantial annual variability in rainfall exists from about 30 inches in a very dry year to as compared to accounting for 80 inches in a very wet year, ultimately affecting the other components (Amatya et al. 2008). The examples of Turkey Creek near Huger (USGS gaging station, drainage area 22.7 square miles) (see Figure 2-14) indicate a flatwoods watershed that may take 12 hours to peak after intense rainfall and 10 to 15 days to return to flow prior to the rainfall event. Coastal watersheds are slower to respond than areas with steeper terrain. Turkey Creek has both ditching and straightening that promotes drainage and dikes that may delay or prevent it.

However, time of year can also make a big difference. The growing season pulls the water table down faster through transpiration, so the hydrologic response may be lessened and delayed as water is absorbed and ground water levels decline. Some vegetation may use more water than others, and this depends to some degree on the availability of water in the soil, extent of root system, and ability for the species to conserve water by regulating the opening and closing of the stomata. Pine can use substantially more water than hardwoods or grasses as their stomata remain open or at least do not shut down as tight during dry conditions, so they tend to use more water (Swank et al. 1988).

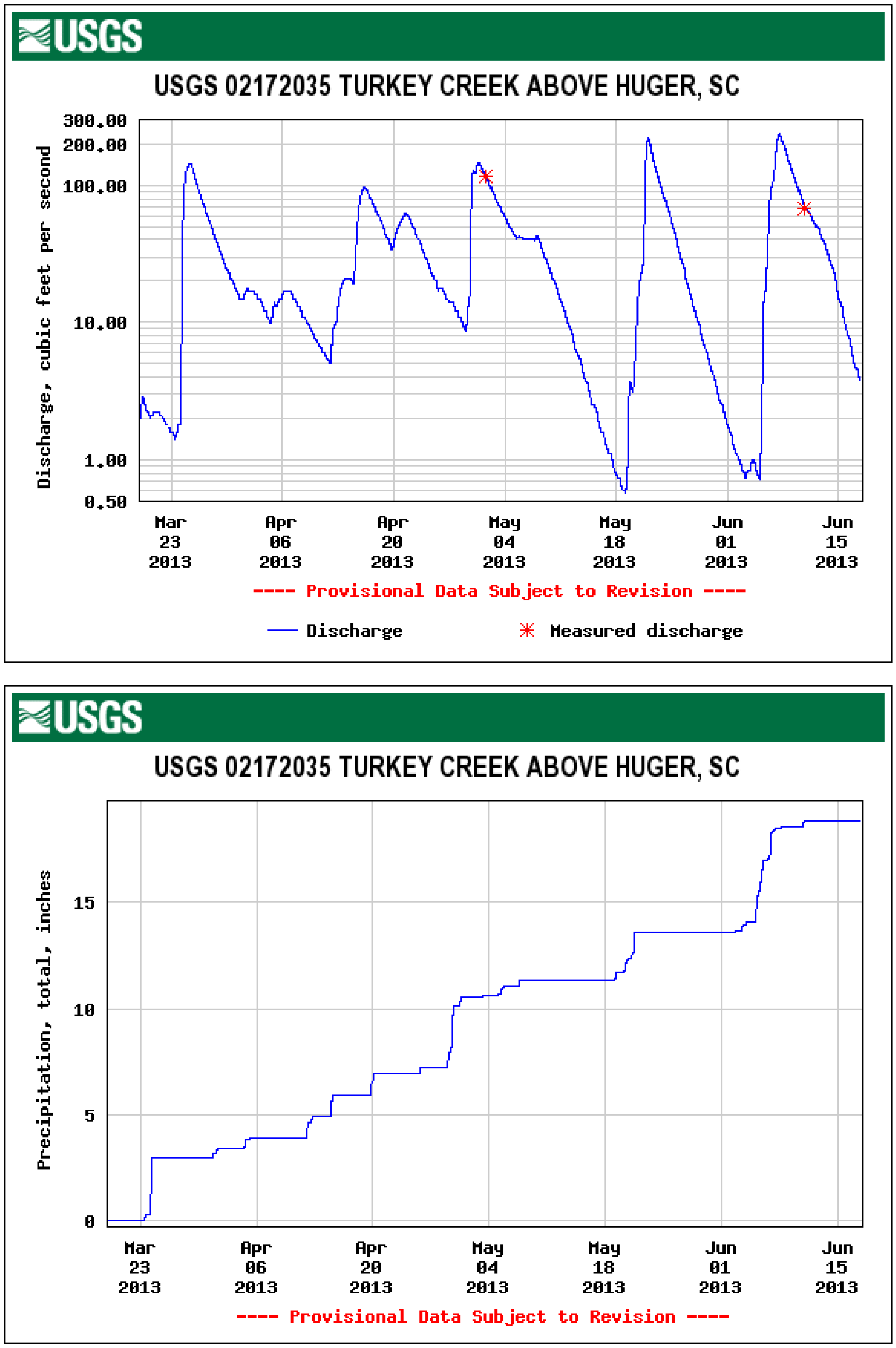


Figure 2-14. USGS graphs for precipitation and discharge for Turkey Creek

In hydrologic modeling of the southeastern U.S., Sun et al. (2005) found that reducing transpiration rate estimates for upland hardwoods as beneficial to their water balance modeling efforts for watersheds containing USGS stream gauging stations to be consistent with water yield. Dr. Tom Williams, retired Clemson hydrologist from Belle Baruch, has indicated that this effect may be lessened where water is highly available in the coastal plain, as bottomland hardwoods may use as much water as pine in those circumstances. Too much water, such as in wetlands that remain flooded or saturated well into the growing season, develop anaerobic conditions that may slow some plant processes and water uses unless they have special adaptations to increase oxygen or perhaps root support (e.g., aerenchyma in some vegetation, advantageous rooting like cypress knees for support). In persistent flooded conditions evaporation may increase while transpiration is reduced. Whether pine or hardwood, extensive regeneration of forests will temporarily reduce transpiration and increase site moisture conditions until the forest is reestablished. With the heavier dependence on thinning and leaving residual stands for regeneration, specialized woodland or savanna habitats, the increase in site moisture after operations is probably less of an issue than when clearcutting was common.

Hydrologic Modifications

Note: This section discusses dams, canals, ditches, roads, trams, bedding, and dikes, etc.

Hydrologic modification practices were common in early America (SC Regulations, 1911, 1920 to 1962; Happ 1945; Berkeley County et al. 1963; Trimble 1974; Schumm et al. 1984; Trettin et al. 2008). Many early land uses applied some degree of hydrologic modification to streams, riparian areas, and wetlands ranging from temporary to relatively permanent changes. Few restoration efforts have been used to reverse these hydrologic changes. Continuing efforts to modify hydrology were encouraged by the State legislature and counties into the early 1970s (SC Regulations, 1911, 1920 to 1962; Berkeley County et al. 1963). The general perception was that “swamps” were impediments to access and contained foul water. Substantial efforts to drain the swamps to improve access (roads and rails), agriculture, pine forestry, range, wildlife, development and industry were heavily supported. Nationwide, wetland ecosystems suffered substantial losses.

By the 1980s, the conversion of wetlands on the National Forests had ceased in response to the Executive Order 11990 on wetland conservation signed by President Carter in 1977 and the directives in the Clean Water Act administered by the Environmental Protection Agency, states and Corps of Engineers. Some adjacent landowners during this early regulation period had continued to look for opportunities and took to more inventive ways to modify wetlands, in some instances influencing the Forest. With the heavy vegetation cover, hiding activities from aerial inspection was still fairly easy.

Relative to the 1985 plan, some minor drainage activities such as localized site bedding or mounding of soil with the Brache scarifier for individual pine tree planting sites continued, but the trend for their use was constrained to on-site modifications, and avoiding connectivity to the stream system in order to avoid water quality and potential drainage implications. These minor modifications were well within the regulations that allowed some normal silvicultural and agricultural activities to be exempted. Even though some minor modifications continued on the Forest, the intent to change wetlands to uplands was strictly maintained. Some of the useful equipment like the Brache scarifier almost disappeared from use on the Forest prior to 1996. By the 1996 plan, drainage modifications were not maintained, but in most instances, were never actively decommissioned or removed. Many of these ditches became plugged by debris from Hurricane Hugo and the lack of salvage operations in wet areas or bottomland channels. However, ditches along roads or connected to stream crossings were evaluated to see if debris removal was needed to prevent road flooding and provide passage of water at culverts and bridges. Nonetheless, the 1996 plan continued to have a provision that would allow bedding, piling, and other minor site modifications that would promote or maintain pine over hardwoods or other vegetation.

All subwatersheds with portions of the Francis Marion National Forest currently have numerous hydrologic modifications from roads, dikes, ditches, road crossings, stream straightening, and in some instances, site drainage or severe rutting. Modifications are extensive, with a partial survey of noticeable dikes and stream crossings (does not include canals and ditches) averaging 100 modifications per subwatershed. Most of these are localized, and their current level of effects difficult to determine (Hansen et al. 2013). However, most do not appear to be temporary structures and will continue to influence hydrologic function to varying degrees by restricting drainage (Trettin et al. 2008; Amatya et al. 2013). Apparent on the landscape due to the availability of LiDAR DEMs are ditches, stream channel straightening, dikes and small dams.

In analyzing the road imprint information, an assumption was made that road ditching was not used to help drain the land. But we know that there are instances where roads were constructed in the past to not only provide access, but contribute to land drainage. In other circumstances roads had inadequate or insufficient culvert cross drainage, and sometimes impounded water on one side of the road to the detriment of reduced flow to wetlands on the other side. Lands diked such as rice culture or constrain tidal influence probably had the intent to limit or retain surface water for extended periods of time. Developers probably selected areas to flood that already showed signs of being able to hold and retain water, such as wetlands, and they just wanted to increase or manage the hydroperiod such as to increase the ability to control competing vegetation by flooding or to provide water during dry conditions by storing water. They may have converted some salt to freshwater marshlands, as they would be easier to burn off, rather than clear. Most of the intentional ditching and significant hydrological modifications were stopped prior to the 1985 plan. Ongoing permits for ditch and drainage maintenance are in place with Berkeley and Charleston counties and SC Department of Transportation, but no other information is known about the specifics at this time (Amy Fore, Francis Marion National Forest 2013).

Altered hydraulic conductivity and depth-to-water table were among the effects of skidding logs where ruts occurred due to timber salvage after Hurricane Hugo (Aust et al. 1993). They found that on low gradient land, the upper side of the ditch and the rut would be much wetter, and the lower side would be drier, indicating that the rut was affecting the natural movement of water across the land. The 1996 plan, the SC BMPs, and timber sale contracts address the need to prevent excessive rutting. Firelines or fuel breaks locally may modify hydrology as these were either cut into the surface, or eventually degrade into the surface after repeated use, altering movement of surface or subsurface water patterns. Fire plows were once the standard practice, but they tend to entrench more quickly into the landscape, causing more permanent hydrological impacts and are generally not used as much today, or mitigated by site smoothing following prescribed burn treatment or wildfire. Bladed firelines are more common today and they still can modify hydrology, especially when repeatedly reused, but the modifications can generally be reduced with smoothing and/or installing features that limit excessive capture and transfer of concentrated water to offsite areas. Most practices that were once standard procedures have been evaluated, and measures taken to reduce their level of effect by altering the practice or timing of work.

Some modifications seem insignificant, such as ruts; however, most ruts and especially deep ruts do not recover on their own and exist for extended periods of time. They influence the natural flow pattern of surface and subsurface water, extent and function of aquatic, riparian and/or wetland ecosystems (Aust et al. 1993; Hansen and Law 1987).

In 1985 and 1996 plans, most of the past hydrologic modifications were not as well-known as to their extent and location, and were not identified as something to be improved on the National Forest unless something we caused that needed mitigation. Efforts were made to avoid converting wetlands to uplands, and limitations were put in the plans to avoid site drainage and rutting impacts even beyond what would normally be allowed. In most instances, the conversion to pine was favored where it could be reasonably accommodated and it is not unusual for wet areas converted or restored to pine to reduce the water table from increased transpiration.

Certain hydrologic modifications for wildlife and waterfowl activities were developed many decades ago in attempts to provide hunting opportunities as well as replace some of the lost habitat. Currently, dikes developed for the greentree reservoirs to improve coastal waterbird habitat are being managed and maintained. These developments have been maintained when damaged and continue to provide the desired hunting and habitat benefits. More details on these areas are provided under section 8.6.1.3 "Current Conditions and Trends."

Most of the past site ditching, canals, trams, dikes for rice culture, agriculture, wetland and riparian area drainage, straightened and channelized streams are not currently being maintained. A few adjacent to private lands have long-standing special use permits or agreements for their long-term maintenance to control flooding or other needs on private lands. Modifications associated with roads are being reduced by installing bridges or improved culverts when it is evident they are modifying flow, constraining aquatic passage, or have lost their functional capacity from sediment, debris, or beaver. Continued road maintenance of stream crossing structures are needed to maintain road safety, limit road damage from flooding, and provide aquatic passage. Road ditches and cross-drain culverts are being maintained as needed to keep them functional and where possible, limit the extent of modification. Culverts are cleaned when sediment, debris, or other issues are identified during normal or storm-related maintenance. When road flooding or adjacent site flooding problems are found, the conditions would be earmarked and installation of properly designed cross drainage would normally be planned. The Forest transportation analysis plan (TAP) has some potential to identify road segments no longer needed that may result in decommissioning sections.

There have not been major efforts to evaluate effects, costs, benefits, or needs to remove or reduce the effects of hydrologic modifications. However, it is likely that many of these may need complex project analysis, specific to the situation.

Stream and Aquatic Extent, Types and Classification (Rosgen)

Much of the hydrology was affected by the coastal geology, with a series of alluvial marine terraces, primarily sandy deposits that consist of barriers or dune-like structures, beaches, and general landform that follow South Carolina coastal form. The oceans that once expanded to the fall line contracted and expanded during various periods of geologic time left a series of relatively flat marine terrace terrain. The riverine system is eroded into these marine terraces, and in doing so, becomes the lower parts of the terrain, where surface and shallow groundwater is likely to flow or be intercepted by these depressions in the relatively low gradient landscape. In general, these long, linear, marine depositional features contain flow patterns that often align with the coastal features. Large rivers such as the Santee River have had sufficient energy and momentum to break through the pattern of coastal features, flowing more directly to the ocean. Smaller tributaries have developed their own channel networks within the major geologic coastal patterns. Stream types within the Rosgen classification system most common to low to very low gradient channels include DA (braided, anastomosed, with floodplain), E (sinuous pattern, with unrestricted access to floodplain), and G (gully type channels commonly in steeper terrain or where affected by canals, stream straightening or ditching, with limited access to floodplain). Although dendritic stream patterns are common, trellis forms are found were linear coastal erosion wear lines are evident in the LiDAR shaded relief. Channel gradients have been affected by numerous in-channel structures as well as the coastal geologic patterns. Areas with more gradient tend to be more defined channels; areas with low gradients are often sinuous and/or braided, with less definition to channel form. In the headwaters and some larger depression areas, the demarcation between what is a stream and what is a wetland may not be recognizable. The litmus test may be during major storms: Does the water flow off or reside on the landscape for extended periods? However, considering the riparian linear depressions within the marine terrace landforms, there should be little surprise that with few exceptions, riparian areas also have hydric soils characteristic of wetlands.

Return of the beaver, although the species is not abundant, suggests that they have locations or conditions that they may have once preferred. The periodic droughts would contribute to their relocation. As the adjacent riparian vegetation is often flooded or consumed by their actions, the beaver move into other areas of opportunity. Sometimes road culverts become an easy target or an unavoidable opportunity for the beavers to plug up flow and feast on the adjacent vegetation. Some stream sections flow freely with relatively low, but uniform gradients, while others pass through surface depressions that must fill after dry periods before flow can be passed.

Under some circumstances channel entrenchment or ditching may increase the connectivity with groundwater (water table) which could contribute to flow permanence. However, typically the channel modifications in the sand-dominated coastal areas and probably most other areas are apt to help drain the adjacent water table, reduce flow permanence, and thereby reduce connectivity as stormflow removal is favored over groundwater replenishment with these practices. The extent of flow permanence has not been fully determined, and varies substantially. Efforts have been made to improve the estimate of flow permanence or nearly permanent (i.e., perennial and intermittent streams) by using preliminary information collected by the NC DENR in the North Carolina flatwoods and rolling coastal plain as provided by Periann Russell (2013). With some uncertainty and high degree of data variability from the North Carolina data, it suggests that on average, 27 to 38 acres is typically sufficient to produce an intermittent or perennial stream. Although there would be substantial risk is applying this data to project planning without more ground truthing, this information is useful at a planning level to help estimate stream extent and drainage density. Preliminary riparian and ecological classifications also used this information to estimate the extent of the headwater influence (Hansen et al. 2013; Simon and Heyden 2013). The current stream coverage in the National Hydrographic Database (NHD) and watershed boundaries in the Watershed Boundary Database (WBD) are administered by the U.S. Geologic Survey and considered official, but inadequate for making many of the estimates needed in forest or project planning. Contacts have been made to officially present updates that will lead to approved changes in these coverages before plan analysis and completion.

Added information on flow permanence may be inferred from the GIS intersection of stream channels with the USFWS wetland maps and mapping of hydric soils with water tables near the surface. Stream channel maps are in the process of being improved by using LiDAR shaded relief, DEMs, and flow accumulation models. Several models and attempts are underway to improve the location and estimated extent of the channel network (Hansen et al. 2013; Simon and Heyden 2013). Andy Maceyka of the Forest GIS staff has been instrumental in the LiDAR analyses including stream modeling and digitizing stream and many ditch locations. A substantial amount of work is needed to provide relatively clean path for flow accumulation modeling coverages. Without the cleared hydrologic path from interuptions, theflow accumulation models tend to get diverted and loose channel contact (i.e., run straight) in the flat terrain. Amatya, Panda, and others have also been using this technology on the research watersheds at the Santee Experimental Forest to improve stream and watershed boundary coverages with similar results in improving stream network and watershed boundaries (Amatya et al. 2012, 2013).

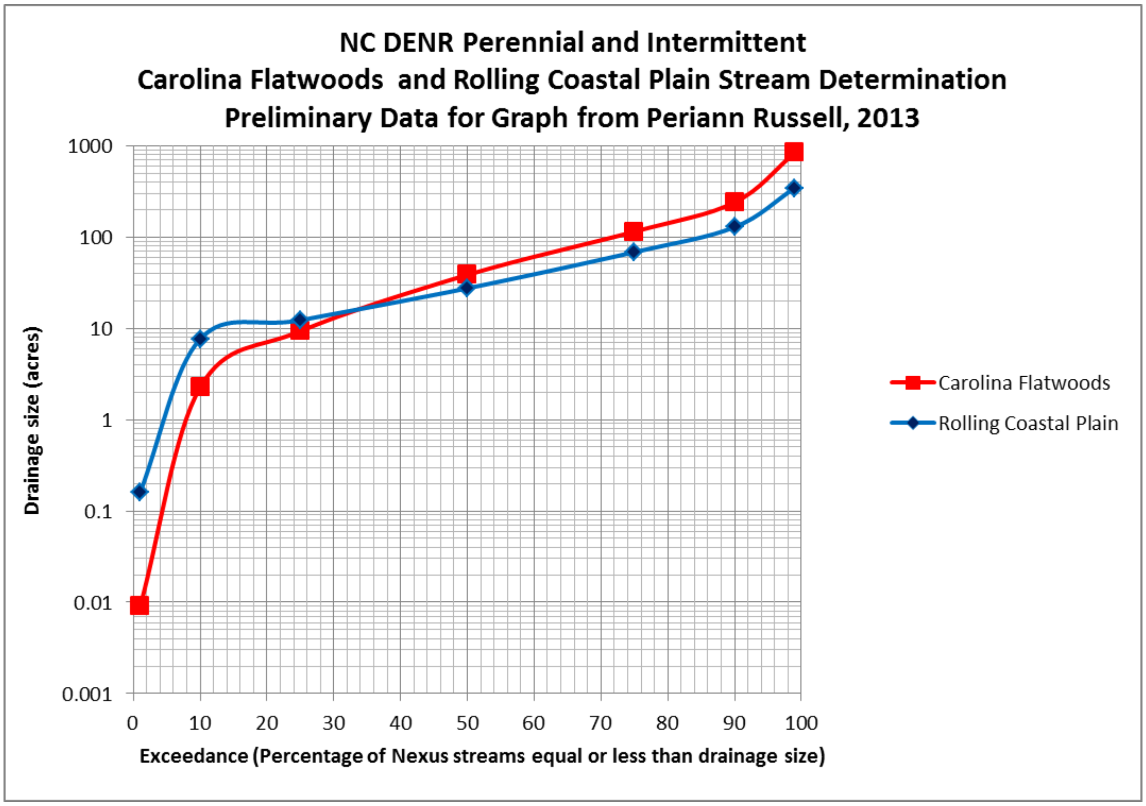


Figure 2-15. Drainage size and exceedance percentage indicates the frequency of intermittent or perennial streams in North Carolina sampling to identify source waters within the Carolina Flatwoods and Rolling Coastal Plain

Source: Plotted from Russell, 2013 data.

Ephemeral streams produce stormflow infrequently in response to effective rainfall events, typically do not have well defined channels, and are not normally in connection with groundwater conditions (i.e., near the water table). That said, we really do not know on a landscape scale where uplands or wetlands end and ephemeral, and intermittent or perennial streams begin. There are remote indicators we look for, but field verification is needed. In some instances, isolated or headwater wetlands and swamps may have ephemeral linear pathways that connect into the recognizable streams, but we do not have the information to differentiate them as either swamp or poorly defined, ephemeral channel, for in some instances, they may be both. If we get 12 inches of rainfall in a tropical storm or hurricane, and depressions fill up and overflow or flow in recognized pathways, are they not then functioning as an ephemeral channel. Also, the ditching for drainage of wetlands complicates these considerations. Substantial areas of the Forest have hydric soils with close groundwater connectivity, so ephemeral streams will often flow into areas with hydric soils, and then do they stay ephemeral, or with the increased groundwater connectivity become intermittent or perennial. When a defined channel emerges, that may be the source point we can recognize, but leaf and needle fall can easily obscure flow passages which may be temporarily noticeable only following significant storm events. If all ephemeral flow channels or pathways were to be identified, looking for flow indicators after a major stormflow event is the most reliable and difficult. They may be found during drier periods by persistent looking for areas where organic debris has moved, sometimes in a sinuous, discontinuous path. Indicators do not always reside on the landscape to be noticed for extended periods. Presently, we assume that portions of ephemeral streams may be within the riparian areas or wetlands, and thus may have more than brief groundwater connectivity. However, we recognize that we are limited in our ability to detect them.

Figure 2-15 indicates a high degree of variability in flatwoods and rolling coastal plain acreage before a defined or Nexus stream begins with recognizable characteristics (Russell 2013). Of all the physiographic areas, the flatwoods is the most variable in the area needed before recognizable streams develop. That is not surprising when applied to the Forest, when we consider the primary geologic landforms include several marine terraces, with some large relatively flat as well as depression surfaces, variable rates and depths of erosion as well as deposits from the riverine, estuarine and marine systems, and some karst interactions and surface connectivity. Factor in the Santee River, one of the larger rivers to enter the Atlantic Ocean within the United States, with notable historic water and sediment loads that helped modify substantial portions of this coastal landscape. Not all the perennial and intermittent channels are well defined in the coastal plain, but LiDAR, infrared photos and flow modeling tools are helpful in estimating their extent.

Connectivity with groundwater resources and floodplains is more common with perennial and intermittent streams. Even though many of the streams have some degree of channelization or straightening, they typically have access to their cfloodplain, except in a few places where there is more gradient and significant entrenchment from flood prevention channelization, gully entrenchment, and development has limited the channel's access to the floodplain. It is evident that in these coastal systems, with shallow water tables, the connectivity between streams and groundwater may be more obvious than normal. Unusual in sloping terrain common to the piedmont and mountains, but in analysis, it became evident that the riparian areas on the Forest in most cases have hydric soils and are also wetlands. This coincidence may in part be a result of the humid, semitropical, well distributed rainfall in coastal areas, but also may be due to the past erosion into relatively flat marine terraces, as the resultant depressions in the relatively flat landscape being fed by subsurface flow and shallow groundwater. In more rolling, hilly or mountainous terrain, the slope of the terrain tends to move rainfall as runoff or shallow interflow more quickly across the slope or to stream channels. Extensive areas with shallow water tables are not dominate in sloping terrain, as they would leak, seep, or form springs that flow to channels due to the topography and erosive materials. Hillslopes do contribute water to floodplains and riparian bottomlands and sometimes wetlands, but not in the same way that the relatively flat marine terraces would. However, during severe drought, groundwater connectivity and streamflow in many perennial streams can be temporarily lost or at least go under the streambed (hyporheic flow) and perhaps continue to some degree in the valleybed or confined subsurface substrates.

More information on groundwater condition and connectivity is provided in the groundwater section that follows.

Freshwater and Marine/Tidal Influences

Although the entire area has been affected by the ocean and tidal influence during earlier geological periods, current extent of freshwater and marine tidal influences are generally fairly well defined, but also modified by hydrologic modifications in the past (Logan 1859; Kemp et al. 2011; Berkeley County et al. 1963; Doar 2013). Expected climate changes could increase tidal influences due to sea-level rise, affecting perhaps 2 percent of the Forest over the next 50 to 100 years (mFigure 2-23). There is generally no accurate line of demarcation, as the tidal influence is not static, and can vary with the intensity of the moon (full and new), storms, wind speed/direction and other factors. Storm severity, also a byproduct of climate change, could also influence the extent of tidal action.

Some of the earliest modifications to the landscape were to provide access to streams and tidal channels for food and other needs. Eventually, roads and trains were constructed to increase access to the city and ports for trade and sale of goods, and these activities were often on uplands. In some instances, taking the shortest route may have resulted in wetlands and streams being filled, and some bridges and culverts added to limit distances or expense. Rice culture used dikes to control the extent and hydroperiod of saltwater and freshwater influence. The dikes acquired at Tibwin Plantation are a significant hydrologic modification that has added critical habitat to the Forest. Their function provide an example of measures used in the past to limit or control the amount of saltwater in favor of fresh or brackish water management for coastal freshwater or brackish habitats for migratory waterfowl.

The largest hydrologic influence to the area is the Santee and Cooper River modifications associated with the dams, diversion, and rediversion connected to the Lake Marion (Wilson) and Moultrie (Jeffries) dams, diversion, and rediversion (St. Stevens). Besides creating relatively shallow lakes, the ultimate diversion of water from the Santee River system to the Cooper River system is linked to the Charleston development, generation of power, and harbor transport.

In reference condition, the Santee River had sufficient baseflow to provide freshwater to the ocean. However, the resultant dams and diversion heavily reduced flows in the Santee River during baseflows (The Nature Conservancy 2005), which allowed salt water entry well beyond the Santee Delta, influencing water quality to Jamestown, South Carolina (Nixon 2004). The extent of this impact is variable with the flow in the Santee River and the height of the tides. Tributary areas such as Wambaw Creek and Echaw Creek, once freshwater, are also affected by periodic salt excursions, especially during low Santee River flow periods with high tides, high wind, or hurricane periods that can push tidal flooding or storm surges further inland (Hansen 2008). We note that there are also other dams within the Santee River Basin that probably affect flows that first reach Lake Marion. The diversion to Lake Moultrie and Cooper River and rediversion back through the St. Stevens Dam accommodate both the need to divert flow into the Cooper River System for water quality and navigational needs related to Charleston Harbor and Port, and as well provide a means to return sediment-laden flow back into the Santee River.

Bill Hansen, Forest hydrologist, and Jeanne Riley, fisheries biologist, were involved with some of the initial FERC relicensing efforts for the Santee Cooper Project, and this involvement resulted in some increased attention on the Forest to monitor for salt water influence within Wambaw Creek that helped to increase the awareness of these issues (Hansen 2007). Publications by The Nature Conservancy and the U.S .Geological Survey have also identified Santee River effects from salinity to water quality and aquatic vegetation. Continued efforts with FERC, Santee Cooper, and Corps of Engineers in relicensing efforts suggest that there may be increased attention to and opportunity to increase instream flows during critical low flow periods, which could reduce or mitigate effects of salt water influence on the lower Santee River and tributary areas.

The Atlantic Ocean Intercoastal Waterway was developed as a safer navigational canal that borders much of the Atlantic coast including portions of the east side of the Francis Marion. Awendaw Creek and Tibwin Creek have direct AIWW connections and Wando River has indirect connection through the Cooper River. All receive tidal influences and areas with tidal marsh dominated by *Spartina*, *Juncus*, or other species. Many of the tidal waters have a few access points where canoes or small boats can be used. Some of these are natural, but most were constructed for access to tidal waters. The Forest also maintains access to various waters including:

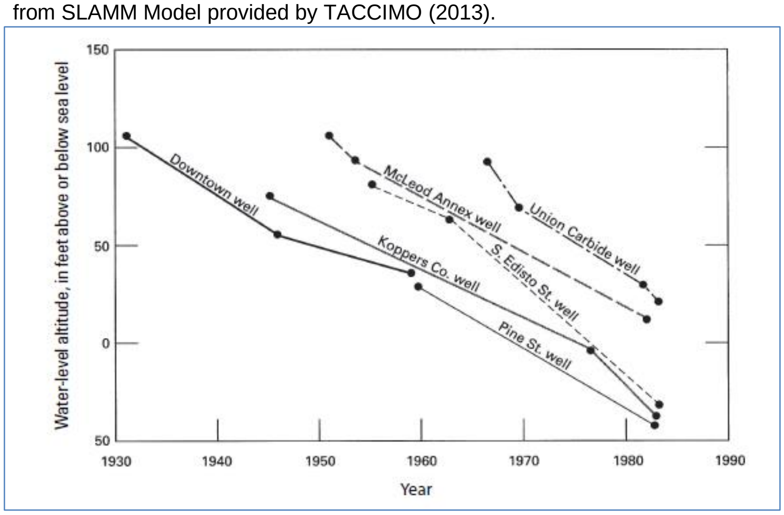
- the motor boat ramp access to the Intercoastal Waterway at Buck Hall,
- canoe access into lower Awendaw Creek,
- small boat access into Wambaw Creek,
- kayak access to Chicken Creek area along the Santee River,
- Santee River ramp access at McConnells Landing,
- recreation facilities at Echaw Creek and Guilliard Lake,
- pond and wetland boardwalk at Seewee Visitor Center,
- Seewee Shell Mound boardwalk and boat landing at Huger Campground.

Groundwater

Surfacial groundwater resources on the Francis Marion have linkages with surface waters and most if not all of the riparian, wetland, and aquatic ecosystems. However, the extent and importance of these linkages are poorly defined, and applicability to this plan will be considered, but unknown at this time. However, some research has been able to differentiate between the extent that rainfall and surface and subsurface waters contribute to streamflow (e.g., Vulava et al. 2008). Substantially more is known about shallow groundwater or surficial groundwater, as well as various subsurface aquifers than can be presented here. Figure 2-23 and Figure 2-24 (copied from Konikow (2013) suggest there has been a lot of groundwater use in the past that contributes to the decline in elevation of water levels within aquifers, with perhaps some apparent reductions as mentioned in section 8.6.1.3 "Current Conditions and Trends." Declines in water levels near Florence, South Carolina, a substantial distance from the Forest near the fall line suggest 50 to 150 foot drop in groundwater levels over the last 15 to 60 years, depending on location. In general, groundwater depletion since 1900 in coastal South Carolina has steadily increased with time, but there appears to be a leveling off of some of the increased uses. The water use information provided in section 8.6.1.3 suggests that most of the groundwater community uses have been converted to surface water uses.

Figure 2-16. Water level declines for selected wells in the Middendorf Aquifer near Florence, South Carolina

Source: From Aucott (1996) as modified from Aucott and Speiran (1985); figure from SLAMM Model provided by TACCIMO (2013).



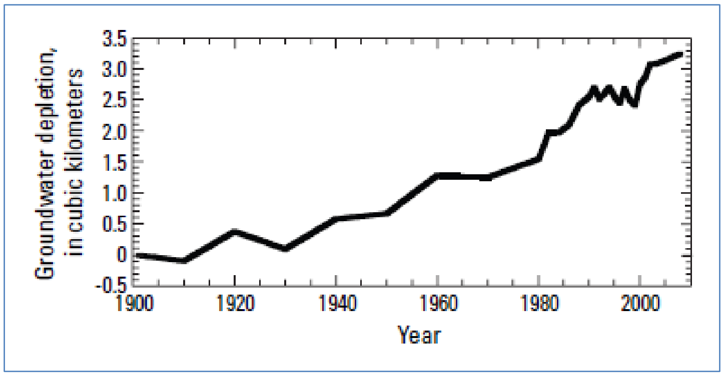


Figure 2-17. Cumulative groundwater depletion in the Coastal Plain Aquifer System of South Carolina, 1900–2008

In general, the subsurface aquifers deepen from the fall line to the ocean and from the north to the south along the coast. Surficial aquifers have similar tendencies and more variability because they are influenced by both surface erosion and variability in marine terrace deposition and erosion. This information will be considered, but the influence on Forest planning is not obvious. Groundwater stream interactions and recharge have been addressed to varying degrees by various studies, including several recently within the Turkey Creek Subwatershed of the Forest (Vulava et al. 2008; Callahan 2010; Callahan et al. 2011; Garrett et al. 2011). Various research works by Dr. Tom Williams (Clemson, Belle Baruch) and Devendra Amatya, Carl Trettin, and other researchers at the Santee Experiment Station are also probably applicable to the groundwater topic for the vicinity. Further interactions may be needed to refine this discussion as well as address to what level this information may have application to the Forest plan and management activities.

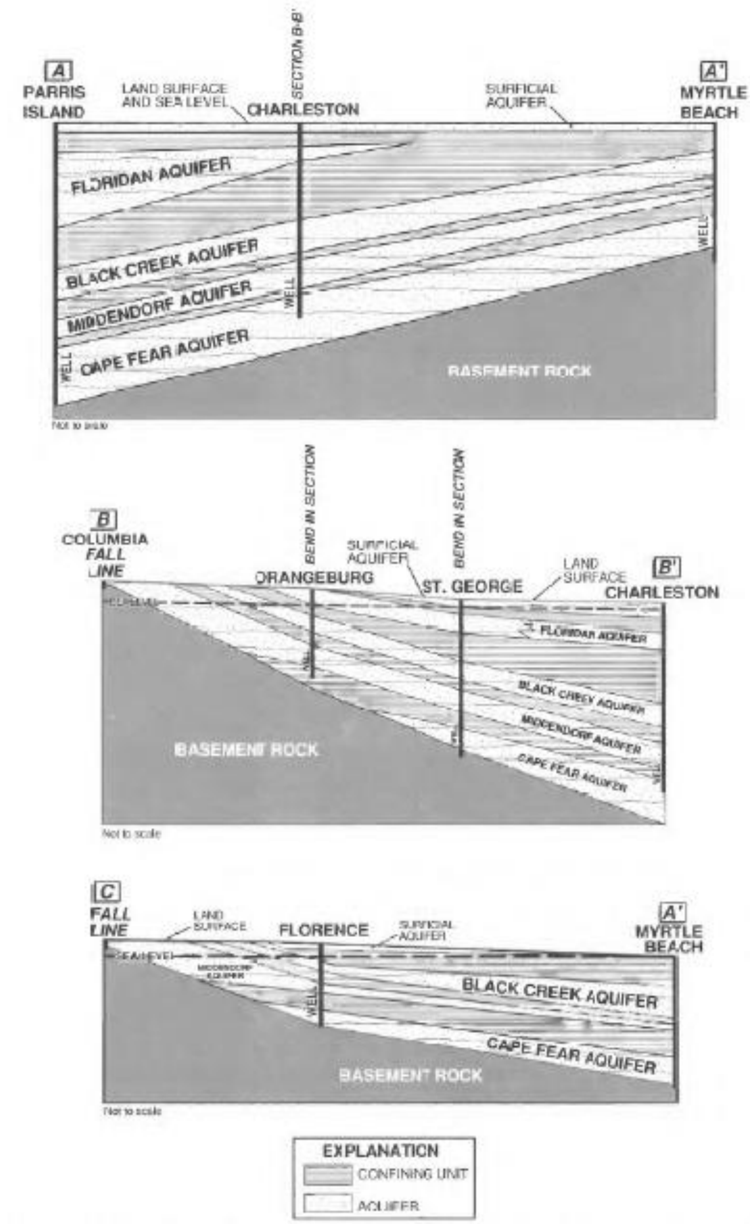


Figure 2. Generalized geohydrologic sections of the South Carolina Coastal Plain. Located in figure 1.

Figure 2-18. Generalized geohydrologic sections of the South Carolina Coastal Plain

Note: Example of the generalized vertical and horizontal groundwater aquifers from the South Carolina fall line to ocean and along ocean front from Parris Island to Myrtle Beach, with Charleston, South Carolina marked. Figure from Cambell and Heeswijk (1996).

2.2.3.6 Stresses and Threats to the Reference Water Resource Condition

With the significant difference between the reference water resource condition prior to major influences of man and the present status of the landscape with the remnants of many hydrologic modifications that have altered surface hydrology, it would be difficult to say that surface water resources could be any more stressed. Many of the coastal streams on the Forest are essentially dry during drought periods. The climate change with more severe floods, winds, and drought could add some additional stresses and threats to the streams and aquatic resources as well as the those within the tidal interface. However, it would be hard to imagine anything much worse than the direct hit of Hurricane Hugo to the Forest in 1989. Expanding urbanization, population, and associated water needs and demand, could materialize into additional stress/threat issues. Some of the past actions that have resulted in threats and stresses could be addressed, reversed, or restored to help offset their impacts in the future. Groundwater threats seem to have dissipated because most communities and municipalities have moved to treating surface water sources for their needs. However, continued attention may be needed on this issue. There are influences outside of the national forest that contribute stresses or threats. The activity of mining in the Dutart Creek vicinity has not shown up as significant ground water use reportable to SC DHEC as perhaps it is under the 3 million gallon monthly use criteria for reporting. Nonetheless, groundwater uses in karst areas found nearby is a concern relative to land subsidence and accelerating sink hole development. Groundwater contributes to and drives many of the riparian and wetland ecosystems, so there is concern when nearby activities contribute to the water table that has been effected by past activity. There is substantial data on groundwater collected by the Santee Experiment Station, College of Charleston, Clemson University at Belle Baruch that could be brought in relative to the soil types present and site conditions. Most of the data is either of short duration, or long duration without detail. The intent of some of this groundwater data collection was to help show the link between the shallow groundwater and surface water stream gauges. Efforts to model various aspects of the hydrologic cycle of coastal systems attempt to link components such as soil types, rainfall, surface and ground water, stream flow, water quality and land uses are underway at the Santee Experiment Forest with associate collaborators, contributors and researchers with other agencies and institutions. The LiDAR data has helped to increase awareness of the extent of the past and various ongoing changes in contributing to the stresses and threats to water resources as many things were not considered in the 1996 plan.

2.2.4 Water Quality

Water quality is an important aspect of the watershed condition issues already addressed. One assumption that needs to be challenged is that the blackwaters common to the Francis Marion are noted for poor water quality. The tannins that tint the water are from the high level of organic materials contained in wetlands. Due to the slow breakdown of organic materials in wetlands, some nutrients needed for abundant aquatic life may be low or limited, such as sodium, calcium, potassium, magnesium, bicarbonate, and phosphorus so those species present are able to adapt and function under the conditions. The high acidity from organic acids also increases the solubility of aluminum, a negative for many aquatic species. The main surface water quality regulations in South Carolina, in response to the CWA directives, include R. 61-68 Water Classifications and Standards and R. 61-69 Classified Waters (SC DHEC 2012a, 2012b). R. 61-68 Water Classifications and Standards set forth the classifications of South Carolina waters and establishes water quality standards to protect and maintain the existing and classified uses. R. 61-69 Classified Waters compiles the waters of the State by name, county, classification and any designation and a brief description of any site-specific numeric criteria that apply. Reports are prepared every couple of years in SC DHEC 303(d)/305(b) reports, and are the most recent and best source of water quality information we have (SC DHEC 2012c, 2012d). The 303d report identified impaired waters based on a network of water quality monitoring stations across the State, and it identifies impaired waters for various water quality attributes or conditions, some of which are linked to aquatic life indicators. The 305b report describes the State's water quality programs and gives the analysis, status, progress, and conditions of the State's waters.

Section 303(d) List

For waters that have pollutant impairments (i.e., those waters that are listed on the CWA Section 303(d) list), the following are listed stream segments in or near the Francis Marion.

The primary listings are fecal coliform that affect recreational uses or for shellfish gathering waters including Awendaw Creek, Guerin Creek, Wando River, Turkey Creek, Cane Gully Branch, Wadboo Swamp, and Echaw Creek (SC DHEC 2012). Listings for mercury include East Fork Cooper River near Quinby Creek, Wadboo Creek, Santee River below Wilson Dam, diversion and rediversion canals, and Wambaw Creek. The entire coastal marine and estuary areas have been identified as a water quality advisory for fish consumption issues (SC DHEC [map available]). Lakes Marion and Moultrie and well as other major streams are also included.

Table 2-26 identifies total mean daily load (TMDL) target dates that are to be addressed with implement plans to treat the water quality impairments by SC DHEC and affected parties.

TMDL TARGET DATE	BASIN	HUC	DHEC STATION LOCATION COUNTY USE CAUSE
2025	SANTEE	30501120101	ST-532 SANTEE RIVER BELOW LAKE MARION (WILSONS) BERKELEY FISH HG
2025	SANTEE	30501120105	ST-031 REDIVERSION CANAL AT US 52 (SC-037A) BERKELEY FISH HG
2025	SANTEE	30501120106	ST-528 SANTEE RIVER @ US 52 (HWY 52 LANDING) WILLIAMSBURG FISH HG
2013	SANTEE	30501120205	RS-02467 ECHAW CK AT PITCH LANDING FRANCIS MARION NATL FOREST BERKELEY REC FC
2025	SANTEE	30501120206	ST-001 SANTEE RVR AT SC 41/US 17A NE OF JAMESTOWN BERKELEY FISH HG
2025	SANTEE	30501120302	CSTL-112 WAMBAW CK AT EXTENSION OF S-10-857 (BRIDGE NEAR BOATLANDING) CHARLESTON FISH HG
2022	SANTEE	30501120303	ST-006 S SANTEE RVR AT US 17 CHARLESTON AL TURBIDITY
2025	SANTEE	30501120303	ST-006 S SANTEE RVR AT US 17 CHARLESTON FISH HG
2025	SANTEE	30502010101	CSTL-079 DIVERSION CANAL AT SC 45 12.6 MI W OF ST STEPHENS (SC-025) BERKELEY FISH HG
2025	SANTEE	30502010101	CSTL-080 LAKE MOULTRIE @ DAM BERKELEY FISH HG
2022	SANTEE	30502010101	RL-02454 LAKE MOULTRIE SW IN OPEN WATER BERKELEY AL NH3N
2014	SANTEE	30502010201	RS-02461 WADBOO SWAMP AT S-08-447 THIRD BRIDGE FROM WEST BERKELEY REC FC
2023	SANTEE	30502010201	ST-007 WALKER SW AT US 52 2.5 MI S ST STEPHENS BERKELEY AL DO
2025	SANTEE	30502010203	CSTL-113 WADBOO SWP AT SC 402 BERKELEY FISH HG
2014	SANTEE	30502010203	RS-03333 CANE GULLEY BRANCH AT S-08-97 6.1 MI NE OF MONCKS CORNER BERKELEY REC FC
2014	SANTEE	30502010301	RS-02483 TURKEY CK AT FOREST SERVICE RD 251 IRISHTOWN FM SC 402 BERKELEY REC FC
2025	SANTEE	30502010304	CSTL-564 EAST FORK OF COOPER RIVER NEAR QUINBYCR BERKELEY FISH HG
2020	SANTEE	30502010401	09B-04 WANDO RIVER AT DEEP CREEK CHARLESTON SHELLFISH FC
2020	SANTEE	30502010401	09B-05 WANDO RIVER OPPOSITE BIG PARADISE ISLAND CHARLESTON SHELLFISH FC
2020	SANTEE	30502010401	09B-06 WANDO RIVER AT PARADISE BOAT LANDING CHARLESTON SHELLFISH FC
2020	SANTEE	30502010401	09B-09 DEEP CREEK - 1 MILE FROM CONFLUENCE WITH WANDO RIVER CHARLESTON SHELLFISH FC
2020	SANTEE	30502010401	09B-10 WANDO RIVER AT ALSTON CREEK CONFLUENCE CHARLESTON SHELLFISH FC
2020	SANTEE	30502010401	09B-12 GUERIN CREEK AT OLD HOUSE CREEK BERKELEY SHELLFISH FC
2020	SANTEE	30502010402	09B-15 WANDO RIVER AT NEW BRIDGE- ROUTE I-526 CHARLESTON SHELLFISH FC
2025	SANTEE	30502010701	CSTL-062 TAIL RACE CANAL AT US 52 & 17A BELOW LAKE MOULTRIE (SC-033) BERKELEY FISH HG
2017	SANTEE	30502090202	07-03 AWENDAW CREEK AT MARKER #57 CHARLESTON SHELLFISH FC
2017	SANTEE	30502090202	07-05 TIBWIN CREEK AT MARKER #42 CHARLESTON SHELLFISH FC
2016	SANTEE	30502090202	MD-268 AWENDAW CREEK AT MARKER #57 (07-03) CHARLESTON AL TURBIDITY
2022	SANTEE	30502090202	MD-796 AIWW TRIB NORTH OF SEWEE CAMP AND SOUTH OF HOUSES CHARLESTON REC FC
DATA FROM SC DHEC 2012 300D LISTING			
USE ABBREVIATIONS - REC - RECREATION, A L= AQUATIC LIFE			
CAUSE ABBREVIATIONS - HG = MERCURY, FC = FECAL COLIFORM, NH3N = AMMONIA NITROGEN, DO = DISSOLVED OXYGEN			

Typically these TMDL plans set waste load limits for polluters or activities as the primary means to affect change. Natural levels of pollutants such as fecal contamination may be considered as allowable background (SC DHEC 2012). Identifiable anthropogenic and other major contributing sources are typically identified for treatment. Elevated fecal coliform with many potential natural sources, including wildlife, make it difficult to address. Individual species can be major contributors, but this can vary, such as geese feeding on livestock forage lands were found to have high fecal contamination from giardia and cryptosporidium as compared to geese feeding from an urban reservoir (Graczyk 1996). Beaver are recovering into some of these systems, and most warm blooded animals contribute to fecal pollutant loading (Tiedemann 2000; Nadareski 2000; Buckhouse 2000).

Table 2-19. Total mean daily load (TMDL) by river and HUC, and target dates that are to be addressed with implement plans to treat the water quality impairments by SC DHEC

The impacts of wild hogs are a relatively new water quality concern. Feral hogs tend to concentrate into riparian areas where soil exposure, damage to riparian vegetation, and fecal pollutant delivery to streams is more likely. However, historic reports found by Danaher and Carlson on the Forest reported a total of 392 pigs and 150 cattle were removed from the Waterhorn in 1949, most of which were live trapped and returned to their owners. These were free-ranging pigs and livestock, which were common on the Francis Marion back in the 1940s. This would have been about 1 year after the Waterhorn was designated as a wildlife preserve (about 17,000 acres) via presidential proclamation and fenced. Impacts on water quality from pigs and cattle are therefore not necessarily new, but it has taken a long time to draw the connections between the two. Efforts are underway to reduce wild hogs by capture and removal, but it is unlikely the problem will be resolved any time soon. Urban expansion and population growth contribute additional fecal sources from septic systems, sewage, and wastewater transmission and treatment facilities, pets, and other sources. Storm periods are also apt to deliver excessive fecal loads that must be factored onto the calculations. Shellfish gathering waters are especially sensitive to the fecal contamination and the standard is set low to limit fecal pollution generated by land uses.

In the case of mercury, air born pollutants from coal burning and other sources have accumulated on the land. The conversion of mercury to methyl mercury in wetlands and its bioaccumulation in fish make it a human consumption issue that is difficult to address beyond heeding the consumption advisories (Figure 2-27). The effects of mercury on the fish, water birds, and other fish-consuming organisms are a biological concern (http://en.wikipedia.org/wiki/Methylmercury, http://www.usgs.gov/themes/factsheet/146-00/#wildlife).

Most of the effective dates for the mercury TMDLs will address the identified coastal waters by 2023 to 2025. Efforts to reduce the mercury pollutants will probably be aimed at the emissions from coal burning plants with expected decline in pollutant levels. Although not specifically listed, most blackwater systems dominated by wetlands either have the potential for mercury concerns as wetlands use sulfate reduction to change ionic mercury to methyl mercury (MeHg). Krabbenhoft (USGS) and others have shown that various aquatic organisms, such as mosquito fish, are able to assimilate the toxic mercury as an intermediate step as it accumulates through the food chain and concentrates in certain carnivorous fish such as bowfin and bass. Mercury problems are common in the wetland-dominated, blackwater portions of the Southeast and Northeast.

Although not listed as water quality impairments on the 303d listing, past major hydrologic modification of the Santee River has altered flow in the river, resulting in the reduction of instream flow during baseflow periods. This has allowed irregular fluctuations in tidal salt to brackish water to Jamestown, South Carolina, and also within the lower Santee River tributary channels such as Wambaw and Echaw Creeks. Salt water is heavier that freshwater, so it is sometimes referred to as a wedge as it moves upstream, with salt water on the bottom and freshwater on top. It has also become apparent that some of the low elevation channel structures of the past may have been installed to reduce tidal influence (Berkeley County et al. 1963).

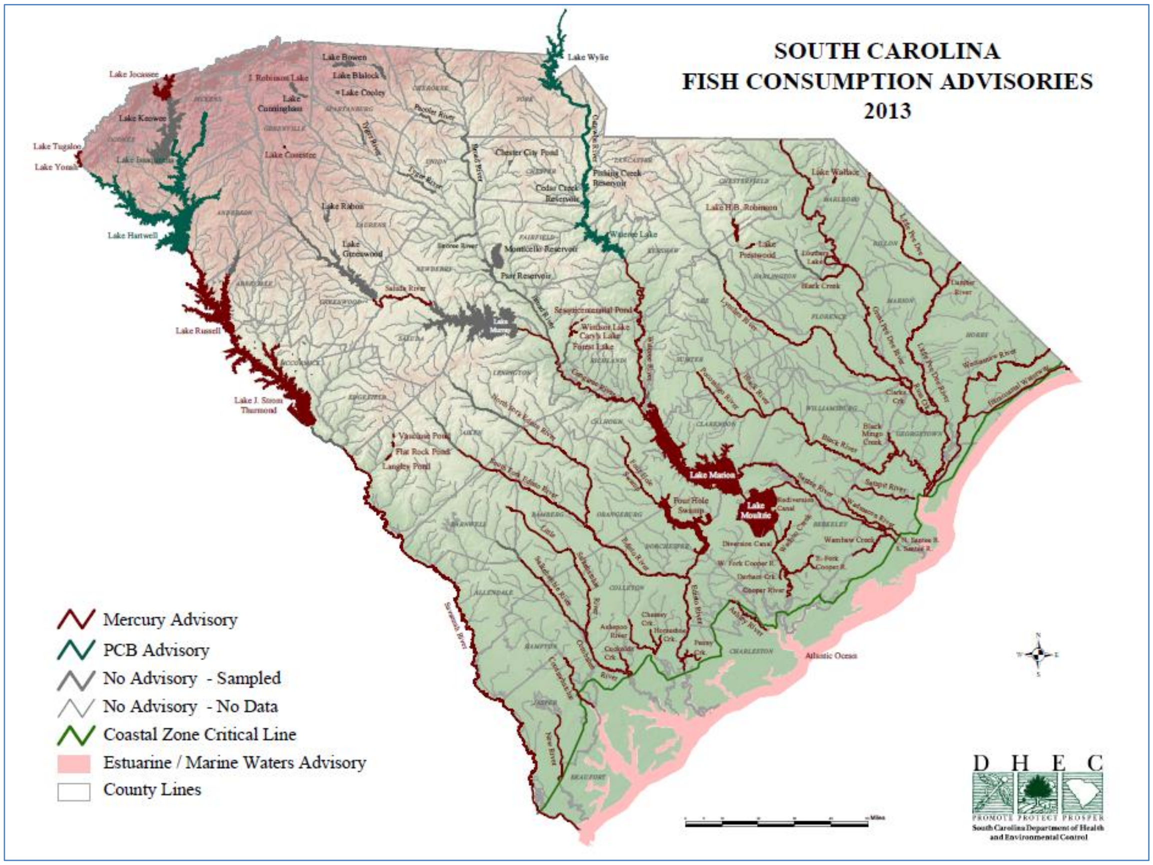


Figure 2-20. Fish consumption advisories for South Carolina in 2013

In the Cooper River system, where low flows are augmented by diversion of freshwater from the Santee River system through Lake Marion and Moultrie for water quality and navigation improvements, salt and brackish water influences may have been locally reduced. Rediversion of some of the flow back into the Santee River system was done to reduce sediment loading into Cooper River that had necessitated increased dredging and channel maintenance. It is not fully known the extent of the effects that numerous other hydrologic modifications to both drain and impound the stream systems have had to water quality and quantity, aquatic, riparian, wetland and terrestrial habitats. However, the Santee Cooper modifications are under consideration in the FERC relicensing, and the needs to increase baseflow into the Santee River were brought up in the analysis.

Climate change discussed elsewhere suggests that over the 50-year planning horizon, as much as 4 percent of the Forest could face some level of change in habitat due to sea-level rise, based on the SLAMM model information provided by TACCIMO. Tidal influence to lower elevation streams is expected to increase. Most of the change would move upland undeveloped land into scrub/shrub transitional marsh. There are limits to the data and a lot of assumptions made in these calculations. There is uncertainty with the climate change effects on streams, and even more uncertainty as to what they will do to water quality. Climate change is another stress/threat that would need to be considered.

TMDLs for turbidity and other water quality components may be identified periodically and included in the 303d report. There have only been a few past turbidity/sediment problem areas associated primarily with new roads and bridge fill containment and a bank failure into

Awendaw Creek at the end of Rosa Green Road. There are local impacts related to ATV use near or in streams and wetlands. Some turbidity can be "natural" in coastal waters due to the combination of freshwater storms and tidal diurnal fluctuations that tend to promote the development of entrenched bare channels, often with some protection from the *Spartina* and other species in the salt marsh. The heavy emphasis of channelization and stream straightening in some areas may have increased sediment sources from raw banks and the undermining of trees and rotational failures that contribute sediment.

Small, community housing development and varying degrees of urbanizing within the outskirts of the Francis Marion include activities that have potential to impact water quality. Subwatersheds with more agriculture, urban, roads, utilities and other development are more apt to have increased erosion and sediments, fecal, and other concerns. The State monitors many of the coastal areas due to their sensitivity and importance to the economy and public uses.

Water quality has been addressed in South Carolina by the State and forest industry for many years. Silvicultural guidelines were the precursors to best management practices (BMPs) (South Carolina Forestry Association 1976) followed with Best Management Practices for South Carolina's Forest Wetlands (South Carolina Forestry Association 1989). The Forestry BMPs set by South Carolina Forestry Commission is in many ways similar to how other states address and maintain water quality and associated resources by altering forest management practices to help minimize or mitigate activity effects (South Carolina Forestry Commission 1994, 2004). Reports relative to compliance and implementation of South Carolina Forestry BMPs highlight the long term success of this program (Adams and Hook 1993; Adams 1994, 1996; Jones 2000, 2005; Sabin 2006, 2009, 2012). Other land use activities also must follow measures to limit water quality effects to be consistent with the Clean Water Act and the Coastal Zone Management Act. Some activities are regulated by the Corps of Engineers and DHEC to ensure water quality consistency with certain Clean Water Act and associated state regulations. Past Forest plans have listed the intent to be consistent with BMPs and other water quality directives (USDA Forest Service 1996, 2012) suggest that continued implementation and increased monitoring are needed, but no substantive changes are needed.

There are reasons for the successes of the Forestry BMP program in South Carolina. For many decades, South Carolina Forestry Association, South Carolina Forestry Commission (SCFC), South Carolina Forest Industry, and the Forest Service have been strong supporters of protection water quality through the use of BMPs rather than regulations to limit the effects of forest management activities on water quality. This emphasis has extended through revising and the publishing of the forestry BMP manual as needed, logger certification, and mill support to take only logs from sites where BMPs have been used. As mentioned, monitoring of and reporting on the compliance, implementation, and effectiveness of BMPs have shown positive results. The Forest is a component of the SCFC BMP monitoring effort and has encouraged BMP compliance checks from SCFC.

Similar practices to BMPs and the national USDA Forest Service direction more specific to the Southeast can be found in the Region 8 Guide for Soil and Water Conservation Practices and in the Coastal Zone Management Act mitigation measures (McLaughlin et al. 2002). Certain activities also mentioned that affect perennial and intermittent streams (waters of the U.S.) are also regulated by the Corps of Engineers (COE) under the Clean Water Act, some requiring a permit. The Rivers and Harbors Act affects activities such as dredging and filling within navigable fresh, tidal, and connected waters including wetlands, and these regulations and permitting are handled by the COE. For some activities, stormwater permits or water quality consistency determinations are needed by SC DHEC for certain ground-disturbing activities.

Hurricane Hugo had heavily damaged much of the Forest in 1989, and in some instances specialized BMPs were developed to avoid water quality and associated site effects during most of the salvage operations. Fortunately most of the operations were on drier sites, but with the transpiration reduction due to trees down, even these areas become wet. Wetland logging continued during infrequent dry periods, but efforts were made to concentrate roads to reduce widespread disturbances, limit rutting with low ground-pressure vehicles and timing equipment entry for favorable ground conditions. Several types of salvage logging were tried including horse skidding; high lead cable; helicopter; and various types of wide tire, duel tire, and low pressure crawler skidders. Road construction required limits that would avoid, minimize, or mitigate impacts to wetlands. Much debris remained in place and contributed to fuel hazards until it eventually decomposed or in some instances mulched or was abated with the installation of a fuel break or fireline. There were, however, infrequent instances of localized, deep rutting and soil puddling that occurred. At that time, the thought process was to try to minimize deep rutting by placing logging debris in the ruts and continue to use them, as it was preferred to limit damage designated areas as opposed to rutting up an entire area with dispersed skid trails. Review of emergency salvage plans and BMPs may be needed to ensure consistency with water quality protection and up-to-date with information technology.

Current trends for harvesting wetlands or wet conditions where rutting may occur are increased awareness to recognize soil type and the frequency and duration of wet periods, and include contract specifications that delay harvest until the ground is dry or operable enough to support equipment. Effective timing of activities has been shown to reduce effects. However, harvest delays on some areas may extend for months or years, so efficiency is reduced. Also, time delays may reduce the quality of the salvaged hurricane-damaged timber. In this instance, the delays can limit the ability to sell the product and can result in an eventual fuel hazard if not salvaged. Areas with extensive storm damage or recent regeneration or vegetation clearing have marked reductions in transpiration, with increased standing water or saturation, runoff, and/or evaporation. These changes in the water balance are typically short term considerations for forest management activities, but could last to some degree for 5 to 10 years.

Sediment is typically addressed with forestry BMPs as one of the bi-products that can be connected to forest management. The current condition relative to estimated suspended sediment concentration for all current or known land uses over a decade for all the subwatersheds is presented in Figure 2-28. The concentrations are based on a sediment delivery ratio of 10 percent and an annual water yield of 10 inches. These values between 5 and 35 ppm are only estimates to indicate the relative differences in ground-disturbing activities within the subwatersheds. Figure 2-29 shows the estimated tons of sediment from the major ground-disturbing activities for each subwatershed for a decade, and gives a better idea of where the likely sediment sources are. Subwatersheds range in size from 10,000 to 40,000 acres, and these numbers were not adjusted for these differences. The values presented in Figure 2-29 are adjusted for the acreage differences. Coefficients used for these are based on the RUSLE and SCS estimates of erosion and the procedures used and associated references were summarized in Hansen et al. (1994). Geoff Holden, Forest GIS Coordinator, has automated this analysis for forest and project planning uses (Hansen et al. 2013). These estimates contain many assumptions and uncertainties, and are normally used to compare alternatives with varying degrees of ground-disturbing activities and ongoing land uses. They are rough estimates that include current and likely work for each decade insofar as could be estimated, but should not be considered as verified or accurate values. In this instance, they are presented to approximate, display, and/or compare the relative differences in subwatersheds for estimated sediment concentration and estimated sediment production by major activity or land use.

2.2.4.1 Stresses and Threats to Water Quality

Compared to the reference water resource condition, there are numerous legacy and ongoing activities that can influence water quality. The general trend is probably increased growth and urbanization to this area, with associated stresses and threats to water quality from increased population, Forest users, and needs for sewage and waste disposal; more vehicle, truck, and container traffic which increases the chances for spills or accidents. Although we have more tools today than ever before to help evaluate, find, track, treat, mitigate and/or reduce water quality stresses and threats, the resources to address these concerns at the state and Federal levels are more constraining than any time in recent history. The TMDLs identified by the State to address many of the fecal and mercury concerns are encouraging, but it is difficult to say what that might mean relative to the Forest. Many of the coastal streams on the Forest are essentially dry during drought periods, so there are obvious water quality stresses that occur under those circumstances. The climate change projections with more severe floods, winds, drought, and sea-level changes will add some additional stresses and threats. Increasing water demands can also contribute to the water quality stress/threat issues.

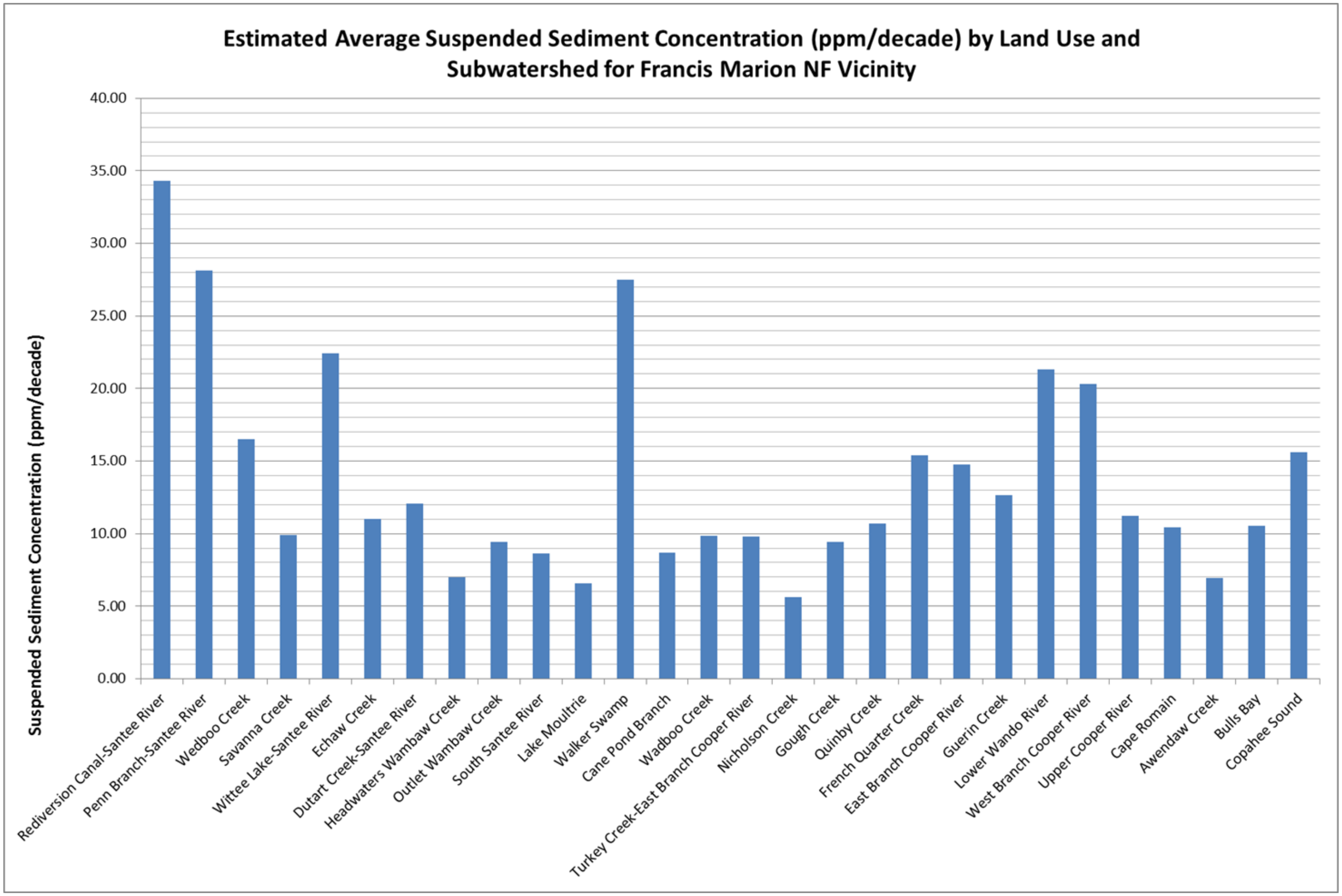


Figure 2-21. Estimated average suspended sediment concentration (ppm/decade) by land use and subwatershed for Francis Marion National Forest vicinity

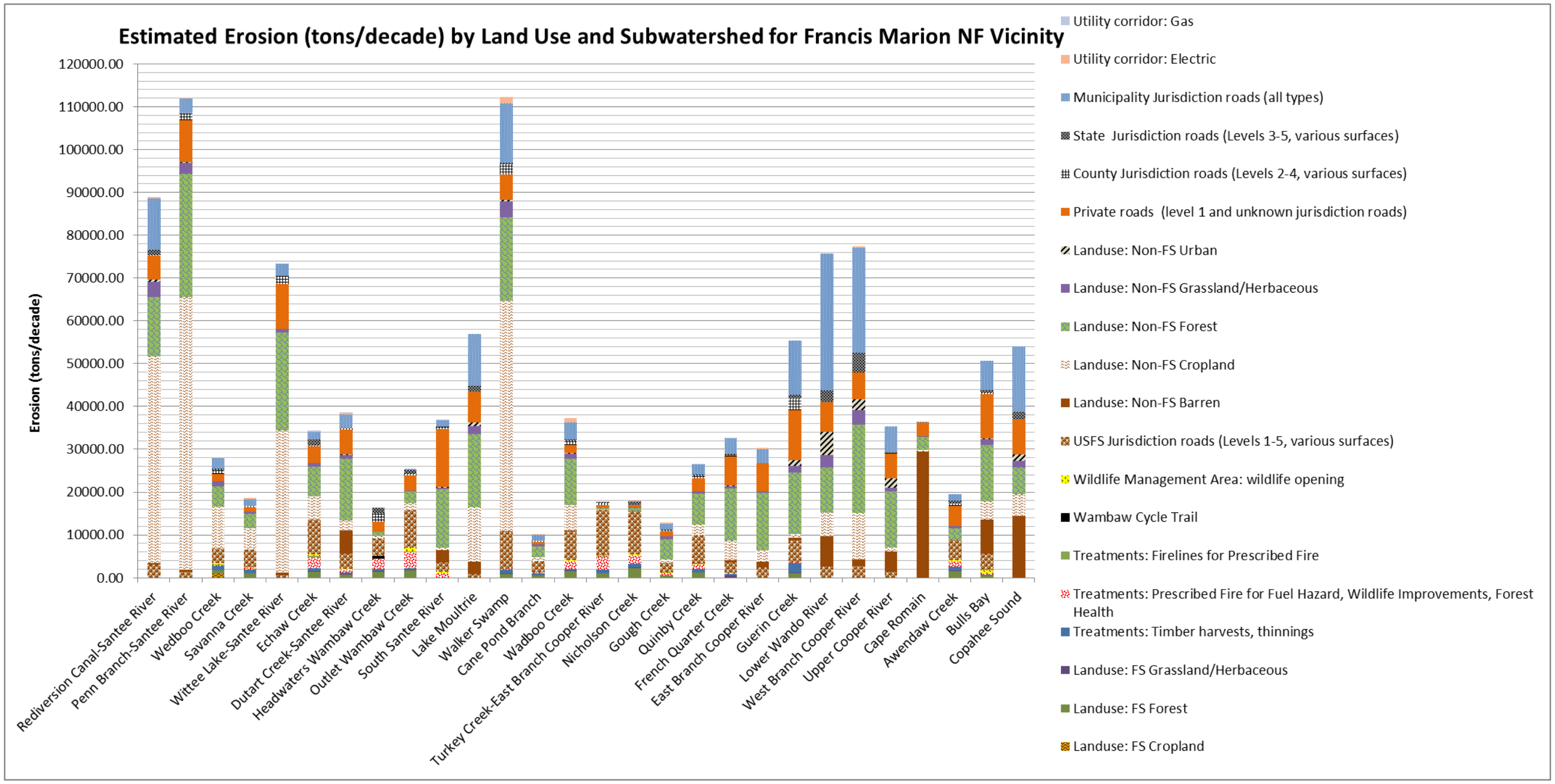


Figure 2-22. Estimated erosion (tons/decade) by land use and subwatershed for Francis Marion National Forest vicinity

2.2.5 Riparian Areas, Wetlands and Waters

2.2.5.1 Preliminary Findings

▶ Forest plans in 1985 and 1996 did not address the effects of hydrologic modification on the aquatic, riparian and wetland conditions. The extent of hydrologic modifications and the impacts to Forest resources and ecosystems were needed for agricultural production, access, pine management, and human habitation. Otherwise the land was typically considered unusable (Logan 1859; South Carolina Regulations 1911 through 1962). Hansen et al. (2013) in LiDAR analysis have found on average over 100 hydrologic modifications per subwatershed. Without direct evaluation, their degree of impact can only be estimated. The hydrologic reference condition for aquatic, riparian, and wetland systems has been substantially altered as past efforts to drain or control the movement and retention of water on the land occurred. Reference conditions would have supported a system with increased hydroperiod, resulting in more viable aquatic, riparian, and wetland systems for some resources.

▶Currently, compensatory environmental mitigation for activities that modify streams, wetlands, and tidal lands or waters are in high demand. The 1985 and 1996 Forest plans did mention the desired conditions for properly functioning streams and associated ecosystems, but direction to restore hydrologic conditions from past activities was not an emphasis. Even when private operations and other public agencies are considered, there is likely to be insufficient mitigation banks or projects that could be available to serve as mitigation for highways, ports, and other public projects. New direction is needed to recognize, and if desired, provide a basis from which to limit or constrain wanted and unwanted proposals, as well as facilitate consideration, collaboration, agreements, and activities that support critical ecological services that offer mutual benefits to the National Forest and public or other entities.

▶The 1996 Forest plan mentioned and gave an accurate estimate of wetland areas, but did not provide direction associated with the different types of wetland areas, such as Carolina bays, depression ponds, pocosins, riparian areas, or marshes. The plan included the need to conserve wetlands and apply BMPs as part of the desired future conditions, but did not suggest their connectivity to stream systems, address past modifications, or mention the need to monitor or track their condition, function, or status. Most wetlands were included within the suitable timber category. Further evaluation and separation may be needed for the Forest plan to address the various types, management, suitability, function, and possibly restoration potential if modified.

▶Current information in the geographic information system (GIS) was used to estimate the extent of riparian areas, wetlands, stream, lake, and tidal margins. Overlap between wetlands, riparian areas, depressions, floodplains, tidal lands, and aquatic elements make clear divisions of elements difficult. Duel designations such as wetlands within riparian floodplains are not uncommon. In 1996, 143,000 acres of wetlands were identified. Currently, the estimate includes 153,000 acres, but this includes embedded streams, riparian, and wetland types. The primary need is to develop improved direction to compare reference, current, and desired conditions. The 2012 planning rule requires that revised Forest plans address management activities in riparian areas. Guidance may be needed for restoration of hydrology and other resources and also to help determine when existing conditions, with modifications, are acceptable.

▶The extent of ephemeral streams is not known or easy to determine in the low-gradient terrain, where many streams are poorly defined or affected by past ditching efforts. Where found, ephemeral streams have some degree of protection with BMPs from limiting excessive ground disturbance, rutting, and crossing with equipment. There may be additional needs for guidance on their location and function, such as a field guide. However, there are no known current issues or direction to suggest a much greater focus is needed on these areas.

▶The current stream coverage, based on the blue line streams found on the USGS topographic maps, underestimates the number of streams and stream locations need to be updated, particularly in the headwaters (Amatya et al. 2008, 2013; Hansen et al. 2013; Simon and Heyden 2013). Continued effort in evaluating the digital elevation models for the stream estimates will help improve watershed boundaries. Upgrading official coverages for streams and watershed boundaries is supported by USGS oversight and should be completed before the Forest plan revision. Many of the streams and watershed boundaries will be updated as improved data generated from LiDAR is incorporated into the GIS stream layer for the Francis Marion. Improvements will reduce uncertainties in Forest planning and analysis.

2.2.5.2 Direction in the 1996 Francis Marion Forest Plan

Riparian areas were not identified in the 1997 Forest plan, but chapter 3 in the 1996 Forest plan contains standards that protect riparian areas. This following list is not all inclusive, but a sample of some of the standards used:

> **FW-108 (R8–VM)** Consult with the Corps of Engineers, Coastal Council and Environmental Protection Agency as necessary for activities in wetland areas and along navigable streams to exchange information and acquire needed permits.
>
> **FW-109 (R8–VM)** In each project, water quality is protected from nonpoint-source pollution through use of preventive “best management practices” (BMP’s). Implementation of BMP’s, monitoring and evaluation of their application and effectiveness, and adjustment of practices as needed are done to protect beneficial water uses and comply with State water quality laws. BMP’s are applied to all activities. In each project, site-specific conditions must be assessed, and the BMP’s needed to meet state water quality standards must be employed.
>
> **FW-113 (R8–VM)** Aquifers and public water sources are identified and protected. The state is consulted to ensure compliance with their ground water protection strategies.
>
> **FW-115** Maintain a near continuous (unbroken) canopy of vegetation for 30 feet on both sides of perennial streams and water bodies. Resource management activities may be implemented if riparian conditions are maintained or improved and the natural supply of large woody debris into the streams and water bodies is not impaired.
>
> Timber harvest methods that ensure a residual basal area of 50 percent can be utilized when managing a zone from 40- 70 feet on perennial streams and water bodies and 40 feet on either side of intermittent streams. Use of mechanical equipment will be limited to protect the riparian and water resources. Additional zones adjacent to riparian areas and ephemeral streams can be established as necessary to meet site specific conditions and management objectives. The width of the zones will depend on slope, vegetation and soil conditions. These zones will be managed to protect soil and water resources by the types of management activities in these zones and controlling the use of equipment.

Ephemeral streams in the low-gradient flatwoods are difficult to identify, let alone evaluate their connectivity with surface waters, proximity to groundwater, or contribution to riparian areas or wetlands. The 1996 plan had direction to follow BMPs, which limit ground-disturbing effects to ephemeral channels in so far that water quality would be impacted. Unless there are other reasons to suggest otherwise, such as wetland or riparian indicators, ephemeral streams on the upland landscape would normally not be considered part of riparian areas or wetlands, would not have stream management zone or other special management beyond those practices described in the BMPs. If there are aquatic or riparian habitat needs pertaining to ephemeral channels or linear-flow depressions, they should be addressed in the aquatic section.

In 1985 and 1996 plans most Forest areas were suitable for timber production, including riparian areas, such as management area 29–Swamps and Swampy Flats, had 15,171 acres suitable for timber production and 5,644 acres unsuitable. Riparian areas and wetlands were for the most part considered manageable for timber production, if done properly. With the Sumter and other Southern Appalachian Assessment Forest Plans identifying the riparian corridor as unsuitable, a renewed look at suitability for timber management for consistency may be needed.

In the 1996 Forest plan, we recognized that about 50,000 acres of pine lands had hydric soils and would classify out as wetlands, since both loblolly and longleaf pine are considered facultative species that can be present in both upland and wetland ecosystems. It is uncertain how many of these lands were pond pine, a facultative wet pine species. Much of the mature pine lands were heavily impacted by Hurricane Hugo, so there was no push to constrain timber harvest or salvage residual areas by identifying all hydric soils (wetlands) as unsuitable for timber harvest. It was generally believed that Forest standards and guidelines, including BMPs, would limit the management effects to acceptable levels for riparian areas and wetlands. No substantial degree of monitoring has occurred to substantiate this. Issues identified with ATV trails and damage to wetlands has been mostly addressed, but recurrent impacts are expected from off-trail uses.

The 1996 plan included the desire to avoid converting wetlands to non-wetlands, but really lacked discussion on the various types of wetlands or the potential for wetland improvement or restoration. Continuation of practices to maintain former site modifications of wetlands were allowed in 1996, but were seldom used or needed. Some modified areas damaged by Hurricane Hugo and not salvaged or burned may have converted back to hardwood or wet savanna if burned. Burning in combination with drought may also favor establishment of these pine into some wetland areas. In 1985, fertilization with phosphorus was also used to favor pine establishment and growth in some wetland areas (McKee and Law 1985).

2.2.5.3 Definitions

Definitions of terminology from the 2012 planning rule used for this assessment:

> *Riparian Areas* ~ Three-dimensional ecotones (the transition zone between two adjoining communities) of interaction that include terrestrial and aquatic ecosystems that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at variable widths (36 CFR 219.19; see appendix A for more information).
>
> *Riparian Management Zone* ~ Portions of a watershed where riparian-dependent resources receive primary emphasis, and for which plans include plan components to maintain or restore riparian functions and ecological functions (36 CFR 219.19: see appendix A for more information).
>
> *Wetlands* ~ Those areas that are inundated by surface, or groundwater with a frequency sufficient to support, and under normal circumstances does, or would support, a prevalence of vegetation, or aquatic life that requires saturated, or seasonally saturated soil conditions

for growth and reproduction. Wetlands generally include swamps, marshes, bogs, and similar areas (40 CFR 232.2) such as sloughs, potholes, springs, seeps, wet meadows, river overflows, mud flats and natural ponds (Executive Order 11990, "Environmental Laboratory," 1987; Mclaughlin et al. 2002).

2.2.5.4 Introduction

Riparian Areas. Initial efforts were made to differentiate riparian areas from wetlands, streams, lakes, and other aquatic habitats. However, there is overlap and there may be differences of opinion or inconsistencies between hydrological and ecological classifications, and acres could be easily lost, double counted, or misrepresented. For this assessment, riparian areas may include some wetland and aquatic areas that overlap or cannot easily be differentiated. Riparian areas include areas that:

- Border perennial and intermittent streams, i.e., transition area between lotic (flowing) streams and uplands. This is the primary definition of riparian areas.
- Areas within the 100-year floodplain are included. These areas contain primarily hydric soils (wetlands) because they are eroded, linear depressions into relative flat marine terrace flatwoods within the humid semi-tropical climate, and the apparent tendency in this circumstance is to have shallow water tables.
- Unless differentiated, lotic (flowing) streams and channels are likely to be included.

However, under some circumstances, riparian areas may be combined for discussion purposes with isolated wetlands, aquatic, tidal, maritime, or other areas to make it easier or more efficient to address their overall presence on the landscape or their likelihood to be addressed similarly. Areas that may be considered along with riparian areas include:

- Isolated wetlands such as Carolina bays with no stream connectivity; adjacent upland areas along lotic (flowing) and lentic (non-flowing) waters with non-hydric soils (non-wetlands) if needed to protect water quality or aquatic habitat.
- Lentic water bodies such as lakes, ponds, and associated shore areas
- Springs, seeps, and other groundwater dependent ecosystems
- Areas within the 100-year ocean surgezone or floodzone of waterbodies.

In the initial estimates on the Forest, riparian areas include soils that flood or are linear depressions with hydrologic connectivity to freshwater, but some may also be tidally influenced. Riparian areas also typically qualify as wetlands. However, not all wetlands are riparian areas. As far as management, there could be reasons to single out some of the differences between lotic, flowing systems and lentic, non-flowing or static water systems. Some of the differences include energy, transfer of water, nutrients and sediment, habitat, and potential for flooding.

Riparian areas on the Francis Marion are typically dominated by bottomland hardwoods; hydrology includes rainfall, with often additional sources from flooding, shallow water table, or lateral interflow to help maintain them.

Riparian area estimates include bottomland hardwoods along streams, soils with flooding potential, and the 100-year floodplains along perennial and intermittent streams, including tidal channels that may have a mix of freshwater and brackish water. Also included in this estimate are hydric soils with linear depressions that have sufficient gradient to transfer flood or surface water during wet periods to streams. In the former planning regulations, the width of 100 feet along perennial and intermittent streams was considered the minimum or default width that will be evaluated as to their aquatic or riparian function, included in areas that have been modified. Regardless, the extent of riparian areas in 1996 was large coincident with the wetland estimates and it would have been difficult to separate the two. As mentioned, the estimate of wetlands in 1996 was 143,000 acres, and though not discussed in detail, a portion of this amount was riparian, and the default width of 100 feet presented did not apply to the acreage estimate. Approximately 39,000 acres of the Forest are classified as hydric soils that flood (i.e., mapped in the soils coverage as floodplains), and another 109,000 acres are hydric soils with linear depressions and appear to be connected hydrologically with stream systems (Table 2-21 and Figure 2-30). However, the hydric soil linear depressions may have areas with poorly to no defined channels, and in some instances ditching was used to increase drainage rate. That all of the 148,000 acres function as riparian areas along perennial or intermittent streams is probably an overstatement. However, the amount of riparian area is substantially more than mapped as floodplain. Whether these areas are riparian areas or hydrologically connected adjacent wetlands, there is a degree of protection, conservation, and modification of practices that are considered in their management. The 1985 and 1996 plans did not recognize the extent nor the hydrologic connectivity of the stream systems.

As shown, riparian areas, wetlands, and water-influenced areas on the Francis Marion National Forest are a dominating feature, and often a major part of the local landscape. The 1996 Forest plan recognized about 143,000 acres of wetlands (page 15 of 1996 Forest plan). There is some variability in the methods to estimate the extent of riparian areas, wetlands and deep water habitats, as they may include about 153,000 acres employing current analysis tools. The 1996 Forest Plan applied much of the overall direction found in BMPs, Coastal Zone Management Act, Executive Order 11990, but there was no real strategy in what specifically needed to be done to conserve, restore and manage these resources. Desired future conditions did support maintaining these areas as stable and functioning ecosystems, but details relative to how this would be accomplished, any emphasis on rectifying past alterations, maintaining or improving function, and monitoring or tracking were limited. In the descriptions of management areas, it was not that clear what might or should be done with the embedded riparian areas and wetlands to achieve the desired condition. There needs to be clear vision and direction in how these areas are protected, conserved, restored and managed for dependent resources.

Wetlands. There are a variety of wetland types, and levels of detail which can be used to describe them. Isolated wetlands have no identifiable connectivity to flowing streams or riparian areas such as Carolina bays. Tidal or brackish marsh is wetlands that may or may not also have freshwater stream or associated riparian areas connectivity. However, any tidal area is regularly connected to the ocean, and some tidal streams also have freshwater components. Lake or pond shore areas with hydric soils and vegetation that are not part of the flowing (lotic) channel system are wetlands when shallow, or considered deep water habitats when deep (Cowardin et al. 1979).

Wetlands which are isolated depressions embedded into upland areas do not have the same potential for flooding and flow energy typically associated with riparian areas. There may be some species that would occur in a more oxygenated or flowing water system as opposed to an anoxic condition typical of wetlands. If there is flow in wetlands, it may be more like sheet flow rather than concentrated flow paths within confined depression features or channels. The presence of ditching in some of these wetland depressions suggests an increased potential for connectivity to the stream system, and thus may function as a stream unless there are absolutely no indicators of function. However, the practice of ditching and draining wetlands for a variety of reasons in the past alters the hydroperiod and may provide access by predatory fish which are issues for some species.

Estimates of the extent of riparian areas and wetlands will almost always include some embedded waters that would include small- to medium-sized streams, seeps, springs and small ponds. See section 2.1 “Terrestrial Ecosystems, Aquatic Ecosystems, and Watersheds” for aquatic and terrestrial habitat discussions on the Francis Marion National Forest. In most instances, the larger streams and rivers, lakes, and ponds would be picked up in as water bodies in classification, but there is some overlap in the riparian areas, wetlands, and shallow shorelines and water bodies.

Approaches Used to Develop the Estimates of Riparian Areas. For the assessment, determining a final estimate of the different types and extent of aquatic, riparian areas, and wetlands has been difficult. Two approaches were considered (to some degree for an initial estimate), but the final estimate used a combination of the two approaches:

- The first approach used primarily hydric soil information provided by Jennings (2013) to be approximately 146,200 acres. This approach includes an estimate of the percent of hydric soils within all soil mapping units.
- The second approach used the 1st approximation ecological mapping by Simon and Heyden (2013) (see Table 2-21) estimating 148,300 acres. The 1st approximation of ecological classification gives an estimate of the different types and extent of wetlands, riparian areas, tidal marsh, and aquatic ecosystems (Simon and Heyden 2013). To some degree, the soils information was also used in developing the ecological classification. For discussion on the terrestrial ecological classification, see section 2.1 “Terrestrial Ecosystems, Aquatic Ecosystems, and Watersheds.”
- The combined approach finally settled on using the soil series information where 95 percent or more of the soil mapping unit was hydric, but combined in the finer scale ecological wetland and pond elements that were outside of the hydric soil units and were not picked up in the soil mapping. This approach did not use the hydric soil percentage by soil series as used in the first approach. This combination approach was enabled with GIS analysis to estimate within the Forest boundary, which includes private lands, and another estimate for just Forest lands. This approach came up with an estimate of 153,100 acres (see Figure 2-30).

The three approaches estimate the combined areas of riparian areas, wetlands, aquatic, and tidal influenced waters and marsh to be between 56 percent and 59 percent of the Francis Marion. Although there appears to be good agreement in the methods, all of the measures rely on soils to a substantial degree for these estimates.

Within the Forest boundary, including non-national forest lands, approximately 222,000 acres were estimated of the 417,000 acres to fall in the aquatic, riparian area and wetland categories (figures intentionally rounded). Of this amount, approximately 60,000 acres were recognized as typical floodplain wetland soils, 148,000 acres were linear wetland depressions with likely connectivity to streams, 6,000 acres of tidal wetland marsh, 1,600 acres water, and an additional 2,300 acres of isolated wetlands such as Carolina bays and depression ponds with no apparent direct connection to the streams, floodplains or linear depressions based on early ecological typing estimates (Simon and Heyden 2013; Hansen et al. 2013). These estimates did not include the flood surge zone along the Atlantic Ocean which flooded much of the land to U.S. Highway 17 in the Forest vicinity during Hurricane Hugo along the coast.

Table 2-3. Riparian area acreage as estimated by ecological classification on the Francis Marion National Forest

Ecological classification includes aquatic, wetland and riparian types on the Forest lands	Aquatic, Wetlands, Riparian Marsh Acres
Carolina Bay Wetland	3,264
Depression Pond (Sink Phase)	204
Depression Pond (Typic Phase)	1,311
Large River Floodplain Forest	3,710
Nonriverine Basin Swamp	2,483
Nonriverine Swamp and Wet Hardwood Forest	80,602
Peatland Pocosin and Canebrake (Carolina Bay Phase)	252
Peatland Pocosin and Canebrake (Typic Phase)	2,027
Salt and Brackish Tidal Marsh	2,568
Small Blackwater River Floodplain Forest and Blackwater Stream Floodplain Forest	11,374
Streamhead Seepage Swamp, Pocosin, and Baygall	76
Tidal Wooded Swamp	5,177
Water	55
Wet Pine Savanna and Flatwoods (Wet Phase)	35,219
Grand Total	148,322

Note: First approximation estimate (Simon and Heyden 2013). Due to different methods, slight differences with soil based estimate (Hansen et al. 2013).

Comparison of Ecological and Soil Indicators Relative to Estimating Extent of Riparian Areas, Wetlands and Waters	Column Labels based on soils							
Row Labels based on 1st approximation ecological classification	Depression	Floodplain	Marsh	Water	non-riparian	Grand Total		total aquatic, wl, riparian, marsh
Altered Land	45	0			33	77		45
Carolina Bay Wetland	1426	1166		1	671	3264		3254
Depression Pond (Sink Phase)	37	15		1	151	204		204
Depression Pond (Typic Phase)	473	286		17	555	1331		1311
Dry and Dry-Mesic Oak Forest	16	74		0	794	885		90
Large River Floodplain Forest	1	3523		62	122	3710		3710
Maritime Forest	70	38	44	1	263	416		153
Mesic Slope Forest	6	134		0	73	214		140
Nonriverine Basin Swamp	2475				8	2483		2483
Nonriverine Swamp and Wet Hardwood Forest	56715	23851	36	0	0	80602		80602
Peatland Pocosin and Canebrake (Carolina Bay Phase)		248			4	252		252
Peatland Pocosin and Canebrake (Typic Phase)	952	1070			6	2027		2027
Salt and Brackish Tidal Marsh	93	64	2197	179	34	2568		2568
Small Blackwater River Floodplain Forest _and_Blackwater Stream Floodplain Fores	5942	4676	0	21	736	11374		11374
Streamhead Seepage Swamp, Pocosin and Baygall	9	57			10	76		76
Tidal Wooded Swamp	1135	3712	4	136	190	5177		5177
Upland Longleaf Pine Woodland (Dry to Dry-Mesic Phase)	0	0		0	7943	7944		
Upland Longleaf Pine Woodland (Dry-Mesic to Mesic Phase)	1	1		0	37382	37384		
Upland Longleaf Pine Woodland (Xeric to Dry Phase)	0	1		0	8527	8528		
Water		0		55		55		55
Wet Pine Savanna and Flatwoods (Mesic to Wet Phase)	4409	0		0	51106	55516		4409
Wet Pine Savanna and Flatwoods (Wet Phase)	35219	0			0	35219		35219
Grand Total	109023	38918	2280	474	108609	259304		153149
Compares intiial ecological classification (Simon and Heyden, 2013) and soil based analysis (Hansen et al, 2013)								
Total aquatic, wetland, riparian, marsh and aquatic combines both approaches								

Table 2-23. Comparison of two approaches used to estimate riparian areas, wetlands and aquatic areas

On the Francis Marion, the 1996 plan estimate was about 143,000 acres of wetlands. In this initial estimate, the amount identified within the Forest for the aquatic, riparian area floodplains, linear depressions, and isolated or ecologically identified wetlands, is 153,000 acres. Essentially, all of these acres have hydric soils or isolated wetlands of various types, with smaller streams and aquatic elements embedded into the values. Approximately 59 percent of the National Forest falls into this category of riparian areas, wetlands, tidal marsh, and embedded waters. About 40,000 acres of the National Forest total are wetlands with hydric soils within linear depressions with likely aquatic and riparian connectivity dominated by loblolly, longleaf, or other pine types. The pine wetlands are about 10,000 acres less than identified in 1996 plan; there is no obvious reason for this; however, it is possible that some of the areas damaged by Hurricane Hugo could not be salvaged and converted to hardwood, hardwood pine, or other types. We are uncertain as to the specifics, but Jay Purnell (*personal communication*, Francis Marion National Forest) has suggested an increase in bottomland hardwoods since 1996. Other possible reasons could be differences in inventory methods or stand mapping.

Various methods may be used to separate wetlands, riparian areas, tidal lands, and aquatic areas into categories. In non-tidal areas, preliminary observations in groundwater-ecosystem-dependent resource sampling suggested that conductivities of water in depression wetlands above 40 micromhos/cm^2 likely had subsurface inputs from groundwater or perhaps interface with karst materials. Areas apparently fed by mostly rainfall or surface flow had lower conductivities. It is likely that there may be additional indicators that could help define and divide wetlands into additional categories relative to their water quality and hydrology inputs (e.g., Vulava et al. [2008] and Garrett et al. [2011]). However, unless there are some biological or other reasons for divisions between wetlands driven by different hydrology inputs, no substantial efforts or information based on hydrology or water quality differences has been used to divide them for planning purposes. In salt water influence zones, the levels of salinity can be used to roughly divide these areas into various types. However, the delineation line between salt and freshwater is not necessarily static or exact, and vegetative indicators are often used. The tidal heights have lunar, wind, storm, and other influences. However, the divisions have been based on best available information for the assessment stage, and separation in types may be presented with the ecological classification, but further refinement may be needed in the plan analysis phase.

There are a combination of specific and general types of wetlands with hydric soils, plants and hydrology indicators on the Francis Marion landscape (Enviromental Laboratory 1987).

- Specific types are generally well confined and relatively abrupt changes from the surrounding areas and may include Carolina bays and other isolated wetlands, pocosins, salt, brackish, or maritime marsh, springs, seeps or various types of riparian wetlands (those within riparian areas are regularly flooded areas along the channel or linear depression areas adjacent to terrace slopes along the low frequency floodplain margins that have slope runoff or seepage inputs). Wetlands may be isolated or have stream connections. Wetlands may be managed to some degree to promote their health and function, but many may be unsuitable for timber production unless they are loblolly or longleaf types. Many of the wetlands in the 1996 plan were identified as suitable for timber management. Most of the wetlands are dominated by hardwood trees.
- Loblolly and longleaf pine dominated wetlands are what could be considered general wetland types, comprising about 40,000 acres on the Francis Marion. It was thought that many of these lacked linear depression connectivity to streams unless previously modified. Recent information suggest that some these areas may be connected through

linear depressions; however, they are more apt to be ephemeral or headwater intermittent stream connections. These wetlands are often natural but in some instances may be modified stands through drainage or bedding, infrequently with drainage ditching. For many of these areas, especially longleaf pine stands, prescribed fire activities are a desired component. These loblolly- and longleaf pine-dominated wetlands seem to have no ill effects from being managed. Pine trees have an incredible ability to transpire water when it is available. Even though managed, these wetland pine stands retain hydric soil, plant, and hydrology indicators, and have some management restrictions and equipment limitations that apply to wetlands. However, if hydrologic modifications are needed to regenerate and maintain their condition in the future, they may be candidates for restoration to hardwoods.

Historical Extent of Wetlands in the State of South Carolina. Most states including South Carolina define riparian areas along streams, and have a tendency to differentiate them from wetlands, where appropriate. There is overlap in the State and Forest Service definitions of riparian areas. Table 2-22 summarizes wetland historical and recent extent estimated in South Carolina. This estimate suggests that 64 percent of the wetlands have been lost as compared to the historical or reference level. Similar, but slightly less, loss occurred across the U.S. At the time of European settlement in the early 1600s, the current U.S. area had approximately 221 million acres of wetlands, which declined to about 103 million acres in the mid-1980s (Dahl and Johnson 1991). Remarkably, 6 states lost 85 percent or more of their original wetland acreage, and 22 lost 50 percent or more (Dahl 1990).

Table 2-4. Extent of wetlands, by type

Wetland Type	Historical Acreage	1980s Reported Acreage	1994 Reported Acreage	Most Recent Acreage
Saturated Bottomland Forest	6,414,000	4,659,000	1,804,884	1,804,884
Nonforested Wetlands/Marsh			485,314	485,314

Source: SC DHEC (2012d).

Comparing the State’s recent estimate of wetlands with the preliminary ecological classification (Simon and Heyden 2013) indicates there are approximately 110,700 acres of bottomland hardwood type wetlands including Carolina bays, and 2,700 acres of nonforested wetlands/marsh on the Forest. These figures suggest that 6 percent of the State’s bottomland hardwood type and 0.6 percent of the non-forested wetland/marsh are contained within the Forest (1.3 percent of the State’s land area). Although there is substantial uncertainty in directly comparing the numbers from two separate estimation approaches, it does suggest that the Forest wetlands are of some significance within South Carolina. In addition, approximately 40,000 acres of pine-dominated wetlands were not included in the State or the Forest bottomland forest estimate. The inference is that the Forest has historically had a substantial decline in wetlands. With currently 59 percent of the Francis Marion estimated to be wetlands of various types including pine-dominated wetlands, there is not enough land left to have the 64 percent decline that South Carolina estimated. This information coupled with the LiDAR coverage that reveals all the ditches and State and county encouragement for drainage, suggests that there probably has been a decline. However, limited effort has been made to determine an estimate of wetland loss for the Forest (South Carolina Regulations, 1911, 1920 to 1962, Berkeley County et al. 1963; Hansen et al. 2013; Simon and Heyden 2013).

Restoration of Riparian Areas and Wetlands. Restoring formerly reclaimed (drained) stands of pine back to facultative wet or obligate hardwood, a mixed stand, or other species may or may not be as simple as not bedding or plugging ditches to allow conversion back to hardwoods (see Table 2-31). Some hydrologic modifications were more or less permanent, while others may only remain effective for the existing forest stand. If maintaining pine is important to some of these prior modified areas, regeneration cuts can be done in stages to reduce tree density and provide openings for regeneration, while maintaining transpiration to the extent that water tables remain low enough for regeneration without bedding. Both loblolly and longleaf pine are facultative wetland species (Table 2-31) that can live either in wetlands or uplands. If for some reason, such as longleaf pine is the desired species on some of these areas, it is fully acceptable to manage for longleaf as long as significant hydrologic modifications are avoided.

Examples of Hydrophytic Tree Species Likely Found in Wetlands of the SE USA		
Obligates (>99% in Wetlands)	**Facultative Wet (66-99% in Wetlands)**	**Facultative (34%-66% in Wetlands)**
River Birch	American Sycamore	Red Maple
Water Hickory	Silver Maple	Gray Birch
Swamp Blackgum	Boxelder	Pecan
Swamp Cottonwood	Shellbark Hickory	Blackgum
Overcup Oak	Slash Pine	Loblolly Pine
Nuttail Oak	Pond Pine	Eastern Cottonwood
Bald Cypress	American Elm	Longleaf Pine
Black Willow	Swamp White Oak	Bur Oak
Water Ash	Laurel Oak	Water Oak
Water Elm	Pin Oak	Slippery Elm
Pond Cypress	Shumard Oak	Rock Elm
	Willow Oak	Green Alder
	Swamp Post Oak	
	Most willow spp.	
	Speckled Alder	
	Hazed Alder	
	Green Ash	

Table 2-24. Potential tree species that could be used for wetland restoration

2.2.5.5 Hydrologic Modifications

Note: Includes ditches, roads, trams, bedding, and dikes, etc.

Hydrologic modifications were extensively discussed already. Most of these have potential for effects to water quantity and quality, as well as effects to riparian areas and wetlands. We have many new tools that enhance our ability to identify modifications, but we lack the information on current status, function, or condition of those areas modified. Recognizing that most of these are obvious with LiDAR technology, and the fact that deep ruts can remain for many decades, it is likely that many of the modifications are functioning to some extent. Severe floods and storms such as Hurricane Hugo may have damaged some of them.

The hydrological modifications across the landscape were designed by early settlers and landowners to improve access, retain water, or to drain areas for various uses or management. Some modifications were intentional, others perhaps not. These activities targeted and affected the hydrology and function of many riparian areas, streams, and wetlands. The full extent of these activities are complex and not fully documented. Activities that promoted drainage, reduced the hydroperiod by increasing the rate of water removal from the landscape, resulting in increased peak and storm flows and reduced groundwater levels and baseflow. Even with the extensive hydrological modifications, changes in soil types occur slowly and adjust very little, but biological changes probably occurred. Some of the drainage modifications influenced the extent and growth of pine lands which have affected the fuel types and loading. Wetlands, riparian areas, and associated lands have different fuel types and fire frequency from the loblolly and longleaf pine lands. However, the assumption would be that dams, ditches and dikes, roads and trams, berms, and beds continue to exert alterations of function resulting from the various types of water controls present.

2.2.5.6 Stresses and Threats

Similar to the reference water resource condition, there are numerous legacy hydrologic modification activities that were directed at to influence riparian areas, wetlands, and waters:

- The general trend of increased growth and urbanization to this area has associated stresses and threats based on water demands and people needs and wants that could influence these resources. The increased population, industrialization, port expansion, and jobs, brings Forest users, development, and many of the other things already mentioned. We have more tools today than ever before to help evaluate, find, track, treat, mitigate and/or reduce riparian area, wetland, and waters stresses and threats. However, resources immediately available to address these concerns at the Forest, State and Federal levels are more constraining than any time in recent history. Many of the coastal streams on the Forest are essentially dry during drought periods, so there are obvious water quantity and riparian connections and stresses under those circumstances.
- The climate change projections with more severe floods, winds, drought, and sea level changes add some additional stresses and threats. There is potential that some of these stresses and threats could be offset or defused with restoration efforts. There are plenty of existing and potential concerns, but there is uncertainty as to how much could be addressed and to what degree and how fast some of these projections might occur.